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DEVELOPMENT OF A WHEELCHAIR SECUREMENT SYSTEM FOR VANS AND SMALL BUSES

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TRANSPORTATION DEVELOPMENT CENTRE

POLICY AND COORDINATION GROUP

TRANSPORT CANADA

February 1989

By

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By

Laurin A. Garland and Suanne L. Dorion

T E S Limited

February 1989

The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre of Transport Canada.

Un sommaire en français de ce rapport est inclus avant la Table des matières.

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The objective of this project was to develop a safe wheelchair securement system for vans and small buses. Extensive information was gathered on wheelchairs, specialized vehicles, securement technology, standards and human factors. Based on an analysis of this data, evaluation criteria were developed upon which to evaluate available wheelchair securement systems. The results were used in the development of several new conceptual designs. Operators of specialized transportation services then evaluated the concepts. The preferred concept (a system of retractable belts/hooks which secure the wheelchair to the floor at four points and which provides a lap and torso belt) was selected for fabrication and evaluation.

The prototype, subjected to an in-house and in-service evaluation by operators of specialized transportation services, revealed several operational deficiencies. The prototype was then modified and re-evaluated. Although the prototype demonstrated the advantages of retractable belts and pivoting bulkhead, it was determined that any further modifications would virtually eliminate the desirable ergonomic design features.

This project demonstrated that the existing four-point belt system is a technically sound and cost-effective measure for securing wheelchairs in accessible transportation. Attachment anchors mounted onto wheelchairs may assist the operator with securement of the wheelchair using a four-point belt system. The standardization of the interface between the wheelchair and the transporting vehicle is the obvious long-term solution to the problem of incompatibility.

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16. Résumé

La recherche avait pour but de mettre au point un dispositif d'ancrage sûr pour les fauteuils roulants dans les véhicules de transport adapté : fourgonnettes ou minibus. Une recherche documentaire a été faite sur les fauteuils roulants, les véhicules adaptés, les dispositifs d'ancrage et sur les normes et les directives en vigueur. L'analyse des données a débouché sur des critères qui ont permis l'évaluation des dispositifs d'ancrage sur le marché; à partir de là, divers concepts ont été imaginé et soumis à l'appréciation des entreprises de transport adapté. L'étape suivante a été de fabriquer le dispositif dont le concept avait été retenu (comportant un ensemble de courroies et de crochets rétractables qui agrippent le fauteuil roulant en quatre points et le fixent au plancher, ainsi qu'une ceinture abdominale et une diagonale) et de le soumettre à une évaluation tant par les chercheurs qu'en service normal par les exploitants.

Plusieurs faiblesses ayant été mises en évidence, le prototype a dû être modifié et réévalué. Cette deuxième évaluation a montré l'utilité des courroies rétractables et des enrouleurs pivotants, mais aussi que toute modification ultérieure ne pourra se faire qu'au détriment des qualités ergonomiques désirables obtenues.

La recherche a montré la faisabilité technique ainsi que l'économie du dispositif à quatre points. Des points d'ancrage permanents intégrés aux fauteuils roulants faciliteraient l'utilisation de ce dispositif. Mais la solution la meilleure serait de mettre au point un dispositif universel qui réglera une fois pour toutes la question de l'inadaptation des dispositifs actuels.

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SUMMARY

This report describes the development and evaluation of a wheelchair securement system for vans and small buses.

The accessibility and safety of surface transportation are of great concern to the mobility disadvantaged community. This transportation provides essential daily mobility to work, shopping, hospitals and social events. For many years, the Transportation Development Centre of Transport Canada has been concerned with improving safety features in vehicles used to transport the elderly and disabled. One of the most important of these safety features is the securement of wheelchairs inside specialized transportation vehicles.

A thorough review of documents pertaining to wheelchairs, specialized vehicles, wheelchair securement systems, standards and guidelines, and human factors was conducted to establish evaluation criteria for a wheelchair securement system. Generic securement systems currently available were then evaluated against these criteria in order to determine the desirable and undesirable features of the different models.

The purpose of the conceptual design stage was to develop concepts which best suited operator, user, technical, and ergonomic requirements. Two concepts evolved and were evaluated against the evaluation criteria for a wheelchair securement system. These concepts were also evaluated by operators of transportation services for the disabled. Operators were requested to rate these concepts against their existing securement systems.

It was decided to proceed with the design and fabrication of the preferred concept, a system of retractable belts/hooks which secures the wheelchair to the floor at four points and which provides a lap and torso belt. The prototype was subjected to an in-house and an in-service evaluation (by operators of specialized transportation services), which revealed several operational deficiencies. The prototype was then modified and re-evaluated. Although the prototype demonstrated the advantages of retractable belts and pivoting bulkhead, it was determined that any further modifications to the prototype would virtually eliminate the desirable ergonomic design features.

This project demonstrated that the existing four-point belt system is a technologically sound and cost-effective means of securing a wide variety of wheelchairs in accessible transportation vehicles. These belt systems meet current performance standards and are an effective interim measure to deal with the incompatibility issue. The approach of making modifications to existing wheelchairs (to provide permanent anchor locations which can be used in conjunction with belt systems currently available on the market) is being investigated. The long-term solution is to address the fundamental problem of incompatibility between wheelchairs and specialized vehicles by providing a standard interface.

SOMMAIRE

Ce rapport décrit la mise au point et l'évaluation d'un dispositif d'ancrage de fauteuils roulants dans les véhicules de transport adapté : fourgonnettes ou minibus.

L'accessibilité et la sécurité des transports de surface sont des questions vitales pour les personnes en fauteuil roulant, qui ont besoin de se déplacer pour leurs besoins quotidiens : travail, magasinage, visites médicales, loisirs. Depuis plusieurs années déjà, le Centre de développement des transports, Transports Canada, cherche à améliorer la sécurité à l'intérieur des véhicules utilisés pour le transport des personnes âgées et des handicapé , notamment par la mise au point d'un dispositif d'ancrage des fauteuils roulants.

Une recherche documentaire approfondie a été faite sur la question et portait sur les fauteuils roulants, les véhicules adaptés, les dispositifs d'ancrage, les normes et les directives en vigueur et, enfin, les facteurs ergonomiques en jeu, dans le but d'élaborer des critères permettant dévaluer les dispositifs d'ancrage. Ensuite, les sortes de dispositifs sur le marché ont été évaluées par rapport à ces critères dans le but de mettre en évidence les qualités et les défauts de chacune d'elles.

Le but fixé à la présente étape, celle de la conceptualisation, a été d'imaginer divers concepts se rapprochant le plus des principes techniques et ergonomiques retenus et des exigences formulées par les exploitants et leurs clients. Les deux concepts mis au point ont été évalué par rapport aux critères établis par les chercheurs, de même que par les exploitants eux-mêmes, ceux-ci ayant été invités à les comparer aux dispositifs qu'ils utilisent et à les coter.

Il a été décidé de passer à la réalisation du concept retenu, un dispositif comportant un ensemble de courroies et de crochets rétractables qui agrippent le fauteuil roulant en quatre points et le fixent au plancher, ainsi qu'une ceinture abdominale et une diagonale. L'évaluation du prototype réalisé a été faite tant par les chercheurs qu'en service normal par les exploitants. L'évaluation a mis en évidence plusieurs faiblesses qui, une fois corrigées, ont nécessité une deuxième évaluation. Celle-ci a montré l'utilité des courroies rétractables et des enrouleurs pivotants, mais aussi que toute modification ultérieure du prototype ne pourra se faire qu'au détriment des qualités ergonomiques désirables obtenues.

La recherche a montré la faisabilité technique et l'économie du dispositif à quatre points d'ancrage et son adaptabilité à une gamme étendue de fauteuils roulants. Ces dispositifs à courroies, en plus de satisfaire aux normes de performances en vigueur, apportent une solution provisoire mais efficace au problème de l'inadaptation des dispositifs actuels. La possibilité d'intégrer aux fauteuils roulants existants des points d'ancrage permanents s'adaptant aux courroies couramment utilisées est à l'étude. Mais la solution souhaitée serait de mettre au point un dispositif universel qui réglera une fois pour toutes la question de l'ancrage des fauteuils roulants à bord des véhicules de transport adapté.

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1. INTRODUCTION

In December of 1986, as a result of a request for proposal, T E S Limited was contracted by the Transportation Development Centre (TDC) to develop a safe wheelchair securement system for vans and small buses. The securement system was to be capable of accommodating the majority of mobility devices (conventional and non-conventional wheelchairs) used by disabled persons and meeting the requirements of specialized transportation vehicle operators. The securement system was to provide two essential functions: i) wheelchair securement to prevent wheelchair movement and to transfer loads from the wheelchair to the vehicle structure, and ii) occupant restraint to restrain basic movement of a wheelchair occupant during transportation and, in some cases, to provide crash protection.

The project was divided into the following phases and stages:

Phase 1 Development of Concept and Preliminary Design

- Stage 1 Information Review
- Stage 2 Conceptual Design

Phase 2 Detailed Design and Prototype Construction, Demonstration and Evaluation of Performance

- Stage 3 Detailed Design
- Stage 4 Fabricate and Demonstrate Prototype

This report presents a comprehensive description of all work carried out during the project.

2. PHASE 1 - DEVELOPMENT OF CONCEPT AND PRELIMINARY DESIGN

This section of the report presents the findings from Phase 1 of this project. A thorough review of documents pertaining to wheelchairs, specialized vehicles, and wheelchair securement systems, including standards and guidelines, was conducted to establish evaluation criteria for a wheelchair securement system. Generic securement systems currently available were then evaluated against these criteria in order to determine the desirable and undesirable features of the different models.

The purpose of the conceptual design stage was to develop concepts which best suited operator, user, technical and ergonomic requirements. Two concepts evolved and were evaluated by operators of transportation services for the disabled. Operators were requested to rate these concepts against their existing securement systems. One concept was selected for fabrication during Phase 2 of the program.

2.1 INFORMATION REVIEW

This portion of the project required a thorough search to accumulate all relevant data held at TDC, on file within the project team and at the Canadian Institute for Scientific and Technical Information (CISTI). In addition, many manufacturers of wheelchairs, securement systems and specialized transportation vehicles, as well as organizations for the handicapped and various government agencies within Canada and the United States were contacted as listed in Appendix "A". Finally, standards and guidelines which govern securement system devices and the human factors involved in operator and passenger usage of securement devices were investigated.

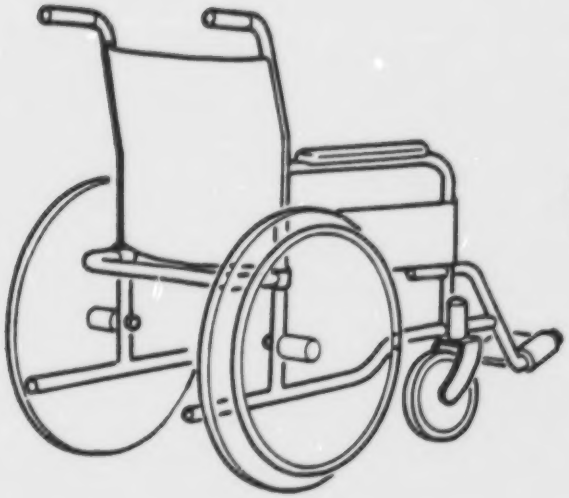
2.1.1 Wheelchairs

T E S Limited reviewed all of the material collected and categorized wheelchairs into the following five generic types:

1. Standard manual
2. Standard electric
3. 3 wheeled chairs
4. 4 wheeled chairs
5. Other

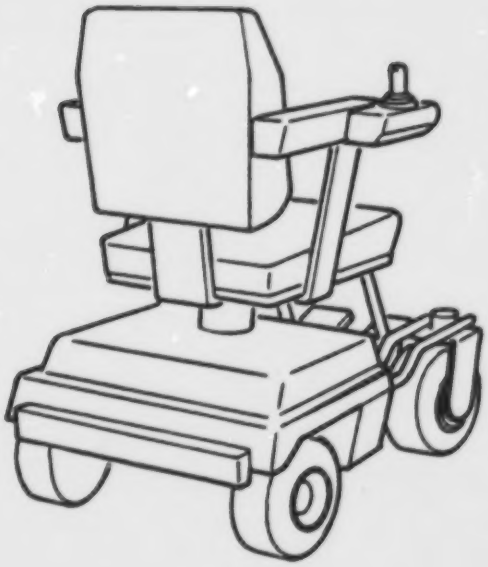
The first two generic types are normally classified as conventional wheelchairs and are characterized by their standard configuration shown in Figure 1A. A standard manual wheelchair is propelled through the hand-rim by the user, whereas a standard electric wheelchair is electrically powered by a battery.

The last three generic types of wheelchairs are classified as non-conventional and are wheelchairs that possess innovative or special features as illustrated in Figure 1B, that differ from the conventional wheelchair. These non-conventional wheelchairs are normally electrically powered since



A

Conventional Wheelchair



B

Non-Conventional Wheelchair

FIGURE 1

Wheelchair Classification

the conventional large rear wheels used for manual operation are not provided. The "Other" classification refers to wheelchairs which do not suit any of the former classifications. Typical examples are the Joey (Ortho-Kinetics Inc.) and the Transporter (Safety Travel Chairs Inc.) models for children.

Numerous commercially available wheelchair models and the range in specifications for the first four generic types are summarized in Appendix "A". Also the space requirements for standard manual and electric wheelchairs including straight line movement and turning spaces are featured in Appendix "A".

The manufacturers of wheelchairs contacted during this project stated that they were continually conducting research and designing new products to introduce into the marketplace, primarily in the area of non-conventional wheelchairs. This was as a result of the wheelchair users desire for more comfortable, transportable and manoeuvrable wheelchairs.

Also, manufacturers of wheelchairs stated that they did not endorse any particular type or manufacturer of wheelchair securement devices to be used in conjunction with their wheelchairs. In some cases, companies manufactured securement devices as well as wheelchairs. However, this is not customary due to the low volume sales of wheelchair securement devices and the low profit margins reported.

Various organizations for the disabled, and medical personnel specializing in physical therapy, agreed in principle that the trends in conventional wheelchair designs are towards lightweight manual chairs such as the Quickie and Quadra models manufactured by Motions Designs and Quadra Wheelchairs Inc., respectively. These sport chairs are illustrated generically in Appendix "A". This design approach offers superior manoeuvrability by the user over other models of wheelchairs and is most appealing to active individuals. The lightweight chairs are usually constructed of either a fixed or a folding tubular frame incorporating sloped rear wheels and small narrow front casters. They also have adjustable back rest heights and variable seat widths. In addition, electrically powered wheelchairs, such as those manufactured by Fortress Scientific (Model 655FS) are also very popular. Conventional manual wheelchairs are still most common in institutions such as hospitals or retirement homes.

Concerns have been raised with regard to the transportation and securement of 3 wheeled scooters and 4 wheeled non-conventional chairs as illustrated in Appendix "A" aboard specialized transportation vehicles. In some cases, operators may refuse to transport scooters.

The scooter population is steadily increasing with the Amigo (Amigo Sales Inc.), Mobie (Everest & Jennings) and 2000FS Electric 3-Wheeler (Fortress Scientific) models currently most popular. In the past, scooters were primarily used by disabled individuals who are able to transfer from a scooter to a regular seat. Currently, however, the scooter appears to have become cosmetically acceptable in society and it has helped to change the general public's perception of the disabled as well as the disabled individuals' perception of themselves. Hence, the scooter is now often used by those unable to transfer.

Manufacturers and distributors of scooters including Ortho-Kinetics, Everest & Jennings, Fortress Scientific, Braun Corporation, Amigo Mobility Centre, and Invacare, were contacted and asked whether they recommended that persons remain seated on their scooters while being transported in vans or small buses. Their responses were negative.

Several operators of transportation services for the disabled were also contacted and, in general, most said that they request that passenger on scooters transfer to an adjacent seat. The scooter is then separately secured during the trip.

2.1.2 Specialized Vehicles

According to a 1986 national survey, there were approximately 330 operators of special urban transit services for disabled persons in Canada. This represents a fleet of approximately 1300 to 1400 vehicles of which 75% are vans and buses equipped with lifts (Ref. 1).

Most urban communities with a population in excess of 25,000 have special transportation services for the disabled in parallel with the conventional transit services (Ref. 1). From discussions with several vehicle operators, it appears that the number of custom built vehicles will continue to increase in the large urban centres. Smaller communities, of less than 25,000 persons, have often made provisions for the disabled when no conventional transit system exists (Ref. 1). Small urban and rural communities are expected to experience a growth of services for the disabled, mainly using cab on chassis type vehicles.

There are four generic types of vehicles used to transport disabled individuals. These include standard van conversions, cab or body on chassis, school bus conversions and custom built vehicles. Several specifications for these vehicles are contained in Appendix "B". All of these types of vehicles offer optional seating layouts to accommodate variations in wheelchairs and ambulatory seating.

Standard vans, either 1/2 or 3/4 ton (most common) with an extended body, are converted to include a raised floor, wheelchair lift and plywood/rubber flooring. These vehicles are capable of accommodating three to five handicapped travellers and a driver. Typical examples of commercially available converted standard vans are the Transit Van (HCI), Paratransit Airporter (Specialty Vehicles Inc.) and the TerraTransit II Van (Turtle Top).

The body on chassis classification represents a 3/4 or 1 ton (most common) vehicle chassis, normally by Ford or GMC, with a specially fabricated body. Similar to the standard van conversions, these vehicles are equipped with a wheelchair lift and plywood/rubber flooring. These vehicles may accommodate 6 to 8 wheelchair travellers. Some examples of body on chassis fabricated vehicles are the Champion TTA, (Champion Home Builders Co.) Bantam Minibus and Handibus (Girardin) and the Mighty Mite (Thomas).

Standard school buses are converted to include a wheelchair lift for transportation of the disabled. These vehicles are capable of accommodating 8 to 18 handicapped individuals depending on the size of the bus. The maximum interior width of 230 cm does not increase with bus length. The body

structure of these vehicles typically involves vertical support/roof hoops, longitudinal side rails and a metal skin covering. The roof hoops act as integral roll bars to provide the required rollover protection as specified in Federal Motor Vehicle Safety Standards. Typical examples of converted school buses are the MT-30 (Blue Bird), Chaperone II and Busette (Wayne Corporation) models.

Custom built vehicles are designed and manufactured specifically for the transportation of disabled travellers. They are equipped with either a wheelchair lift or other device to board wheelchairs. The Orion II uses ramps and a "kneeling" suspension feature as opposed to a conventional wheelchair lift. This vehicle is capable of accommodating 5 to 7 wheelchairs.

There are three lift/ramp locations applicable to most vehicles as shown in Appendix "A". The width of commercially available lifts varies from 81 to 134 cm and the depth of the lifts ranges from 66 to 81 cm.

For any vehicle, the following operator tasks are required for every wheelchair passenger boarding or deboarding.

- In boarding, the operator moves the wheelchair and passenger from the ramp or lift area into the vehicle, manoeuvres the wheelchair and passenger into a designated area, secures the wheelchair and then restrains the passenger. For deboarding, the procedure is reversed.

- When more than one wheelchair passenger and/or destination is involved, a sequence for boarding and deboarding is required.

- Due to the limited space and the seating arrangements typically offered, it may be necessary for the operator to move a wheelchair passenger more than once, in order to allow another passenger to enter or leave the vehicle. This normally involves releasing the wheelchair securements and the occupant restraints, and repositioning the passengers. This increases the time factor at any passenger pick up or drop off point, thereby affecting the cost effectiveness of the operation as well as inconveniencing the passenger.

- The ideal situation is to be able to board and deboard any wheelchair passenger without moving other passengers. The operator determines whether the priority is to be placed on full capacity, with inefficient boarding/deboarding sequences and inconvenience to the passengers, or to systematic boarding/deboarding with a lesser capacity.

As outlined above, there are several operational difficulties associated with the boarding and deboarding of wheelchair passengers. As a result, transit operators select their vehicles and equipment to best suit their requirements. Presently, many transit operators load their vehicles to full capacity, however, the associated difficulties range widely depending on the vehicles, equipment, wheelchairs and passenger destination sequences.

It appears that the use of certain vehicle models is regionally dependent throughout Canada. For instance, the Orion II is predominately used in Ontario, while the Weco manufactured vehicles are featured mainly in the

Western provinces. This differention is largely due to varied funding by the provinces, as well as the unfamiliarity with products from another region.

Most of the operators contacted stated that the interiors of their vehicles were arranged to accommodate forward facing wheelchairs in an effort to comply with CSA D409 and provincial regulations where applicable. The CSA standard, detailed later in Section 2.1.4 of this report, states that wheelchairs must face either forwards or rearwards, thereby excluding the side facing option. It appears that the previously common configuration of positioning wheelchairs sideways to the direction of travel to increase capacity is being phased out of the Canadian fleets.

T E S Limited investigated the potential locations of floor and wall anchorages in the four generic types of vehicles. Generally, the vehicle flooring consists of various gauge metal exterior skin, plywood and rubber matting. It appears likely that the floor structure possesses sufficient strength for mounting of either wheelchair securement or passenger restraint anchorages. In general, it appears that the vehicle structures would be satisfactory in the event of a collision. However, installation of wall anchorages for passenger restraint torso belts would require detailed engineering to confirm or upgrade the existing wall structure. Most vehicles will require local reinforcing to install upper anchorages for passenger restraint torso belts unless this was taken into account during the production of the vehicles.

2.1.3 Wheelchair Securement Systems

A complete securement system consists of a wheelchair securement (Figure 2A) to prevent wheelchair movement, and a passenger restraint (Figure 2B), commonly a seat belt assembly, to restrain movement of the occupant.

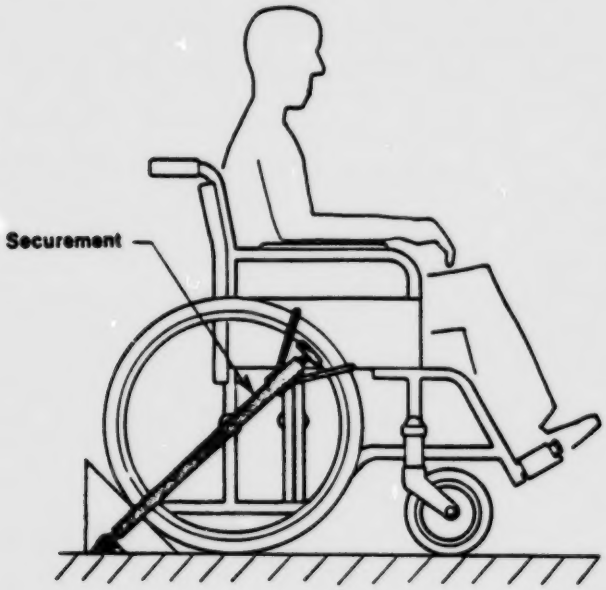
2.1.3.1 Wheelchair Securement

The manufacturers of a wide variety of commercially available securement devices were contacted. The various types of securement devices were classified according to the following six generic designations and are presented in Table 1 along with their specifications.

a) Belts
b) T-bars
c) Rod and Hook
d) Wheel or Rim Locks
e) Floor Mounted Locking Devices
f) Other

Belts

Belts used for securement devices are similar to passenger car seatbelts or cargo belts. These manually operated devices require operator assistance to secure the wheelchair by 3 or 4 points to floor tracks or wall mounts. To provide securement, the belt ends are usually fitted with a hook or other simple bracket for easy attachment to the wheelchair frame. In most cases the belts are secured to the lower frame sections of the wheelchair, however, in some instances the belts are also wrapped around the wheels and/or



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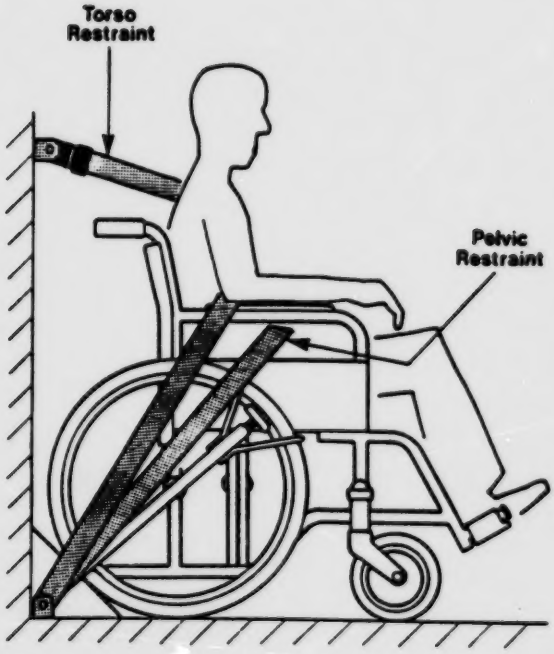

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FIGURE 2

Wheelchair Securement and Occupant Restraint

TABLE 1

Summary of Commercially Available Wheelchair Securement Systems

	Manufacturer or Distributor	Attachment to Vehicle: Floor	Vehicle: Wall	Vehicle: Rim	Vehicle: Tire	Wheelchair: Forward Post	Wheelchair: Caster Arch	Wheelchair: Bottom Rail	Wheelchair: Cross Brace	Wheelchair: Back Post	Cost	Belt: L	Belt: S
A	ABC Enterprises		X	X									
	AMF	X				X				X			
	Aeroquip Corporation	X				X			X				
	Aeroquip Corporation	X				X				X			
	Aeroquip Corporation	X				X				X			
	Brown Corporation	X				X				X	$125US		
	Handicaps Inc.	X											
	Rootes Maidstone Ltd.	X					X						
	Girardin G-straint	X				X				X	$375CDN	Y	Y
	Metallic Component	X				X				X			
	Crow River	X				X	X			X	$119US		
	Crow River	X				X	X				$119US		
	Weco		X							X		Y	Y
B	ABC Enterprises	X						X					
	Ferno Washington Inc.	X							X		$140CDN		
	Mobility Dynamics Inc.	X						X					
	Para Industries (1978) Ltd.	X						X					
	Para Industries (1978) Ltd.	X						X					
	Fred Scott & Sons	X						X					
	Skillcraft Industries Inc.	X						X					
C	Coach & Car	X					X				$65US		
	Drive Master Corp. (1981)	X									$60US		
	Braun Corporation	X					X				$160US		
	Oscar Instruments Co.	X						X					
	R.J. Mobility Systems	X							X				
	Rootes Maidstone Ltd.	X						X			$120US	Y	Y
	C.W. Unwin Ltd.	X						X					
	Greshaw	X					X				$100US		
	Greshaw	X								X	$100US		
D	ABC Enterprises	X	X	X									
	American Seating Co.			X									
	Atlantic Research Corp.	X		X									
	Atlantic Research Corp.	X		X									
	Braun Corporation	X		X									
	Collins Industries Ltd.	X		X							$150US	Y	Y
	Drive Master Corp. (1981)	X		X							$185US		
	Handi-Ramp Inc.	X	X	X							$55US		
	Transi-Lift Equipment		X	X									
	Coach and Car		X	X	X						$105US		
E	Braun Corporation	X				X					$144US		
	Braun Corporation	X									$160US		
	Drive Master Corp. (1981)	X				X			X		$185US		
	Caltrans, Brobeck Corp.	X										Y	
F	Creative Controls	X											
	Falcon	X							X			Y	
	Reb	X		X	X								
	Auto Service	X		X		X							
	Sask. Crippled Children	X							X				
	TDC	X	X		X							Y	Y
	TDC	X	X		X							Y	Y
	Hendersons											Y	Y

NOTE: Source Ref. 4

A - Belts
B - T-bars
C - Rod and Hook
D - Wheel or Rim Locks
E - Floor Mounted Lockins
F - Other Devices
L - Lap
S - Shoulder

armrests. Belt tensioning is usually accomplished through a ratcheting mechanism, over centre cam system or a simple friction lock clasp using a direct pull on the belt for tension.

The front belts are often fastened near the lower area of the wheelchair frame which is somewhat undignified for the passengers, particularly females, during belt attachment and tensioning. The belts are often not stored when not in use and are, therefore, left to become soiled on the floor of the vehicle. Belts will accommodate a large number of wheelchair models but occupant restraint systems are only sometimes provided. The most commonly used belt system in Canada, is the "Q-Straint" (Ref. 2).

T-Bars

T-bars are comprised of a horizontal bar placed between the lower wheels and a rod fastened to the floor, central to the wheelchair. Typically, the bar is attached to the bottom rails or cross brace of the wheelchair by an adjustable bracket. These restraints require operator assistance whereby the operator must kneel down to position the device and attach the bracket under the seat, which is often difficult to access and time consuming. This system often does not prevent the movement of the front end of the wheelchair, does not accommodate all types of wheelchairs, (only standard wheelchair frames), does not provide an occupant restraint system and has no defined storage of the device when it is not in use.

Rod and Hook

The rod and hook classification refers to devices which consist of a steel hook and rod assembly which is custom fitted for each securement operation. The devices usually also include floor mounted pockets for the wheelchair wheels. The custom fitting requires the position of the floor anchors, wheel pockets and rod assembly length to be adjusted for each wheelchair. This system is generally acceptable only for those wheelchairs having a frame similar to a standard manual wheelchair. Operator assistance is required to attach the assembly to the frame, under the seat, and to lock the device with the lever mechanism on the rod assembly. Both operations may be difficult as a result of the areas where the operator must reach and manoeuvre. This system does not prevent front end movement of the wheelchair during travel, often does not provide an occupant restraint and does not have defined storage of the device when it is not in use.

Wheel or Rim Lock

Wheel or rim lock securement systems are usually comprised of a steel, spring loaded, clamping mechanism which automatically secures the rear wheels or rims of the wheelchair to the floor or wall of the vehicle. These devices may utilize rods or pins through U-shaped brackets to secure the rim, instead of a spring loaded clamping mechanism. Operator assistance is not always required in the case of the automatic locking device, thereby reducing the physical effort of the operator and passenger in securing the wheelchair. Manually operated hand or foot controls release the locking mechanism and, in some cases, an electrically operated mechanism is also available. This type of device accepts only standard manual and electric wheelchairs with open spoked wheels. The mechanical device has been known to cause damage to

the wheelchair wheels and rims and an occupant restraint system is not usually included.

Floor Mounted Locking Devices

Floor mounted locking devices consist of a securement bar mounted in the vehicle floor, to which steel brackets, permanently affixed to the wheelchair frame, are attached. This securement requires precise alignment of the wheelchair, does not apply to all wheelchair types, and normally does not include an occupant restraint system.

Other Devices

The "other" classification refers to all devices which are not applicable to the previous categories, such as the TDC MultiModal restraint. This device incorporates securement arms which lock the rear wheels, a three point occupant restraint system and an adjustable back and head support. This manually operated device is difficult to operate on the wall side as the operator is required to bend over the passenger to apply the wall side securement arm. This system was designed for collision forces, accepts standard manual and standard electric wheelchairs, and can be converted into a regular seat when not used for wheelchair passengers. Other restraints in this category include "homemade" devices which were designed and fabricated by operators of handicapped services. The components and installations of "homemade" devices are often untested (do not meet CSA D409 standards) and may tend to damage wheelchairs. As well, a potential safety hazard may be created for the restrained person and the other passengers in the vehicle.

Tests have been conducted (Ref. 3) on most of the aforementioned classification of devices (excluding the homemade devices). Several conclusions were derived including: the systems which rely on tension for securement, as in the case of the T-bar type of devices, tend to become free when the wheelchair deforms and rebounds; the direction that the wheelchair is facing with respect to the direction of impact and the point of attachment are primary variables for the crashworthiness of the wheelchair; the securement of a lap belt around the passenger's waist and the back of the chair results in a potential for internal injury; and, the devices which are designed with the combined centre of gravity of the wheelchair and passenger not considered may cause the wheelchair to tip forward.

The use of certain models of occupant restraint systems appears to be regionally distributed. For instance, the Weco restraint is popular in the western provinces, especially in British Columbia; whereas, the eastern provinces use the three or four point belt systems, primarily the "Q-Straint", the Braun and the Aeroquip devices.

Operator selection of the various securement systems for their vehicles is dependent on the type of service and the requirements of the service provided. For example, transit services which are based on a fixed schedule and route require a quickly deployed securement system which involves minimal driver or passenger involvement. Typically, these devices are incapable of securing non-conventional wheelchairs. Manual or operator assisted devices, generally used in paratransit services, require more time for their deployment but usually accommodate a larger wheelchair population than the

aforementioned restraints. Further, a 1986 CUTA report (Ref. 1) states that the most urgent technical problem, as identified by the Canadian operators, is the wheelchair securement system. This is due to the great variety of wheelchairs used by disabled persons, some of which cannot be safely secured in their existing bus fleets.

Wheelchair users who are members of organizations for the disabled were also contacted. They reported a preference for securement devices which clamp to the frame, as opposed to wheel or rim attachment which may cause damage. In addition, those who are capable of deploying a securement device by themselves would prefer to do so.

2.1.3.2 Passenger Restraint

Currently, there are several passsenger restraint systems used in vehicles for the transportation of the disabled. These include wall and/or floor mounted lap belts, personal torso belts, shoulder straps, and jump seat frame mounted devices. Appendix "C" presents the types of passenger or occupant restraint systems available according to the 1986 survey of Canadian vehicle operators (Ref. 2). A passenger restraint system must safely restrain passengers against the forces that are created by an abrupt deceleration.

2.1.4 Standards and Guidelines

At present, there are no federally regulated standards in Canada or the U.S. pertaining to the transportation of the disabled. The following subsection briefly outlines existing standards or proposed guidelines that have been adopted by various provinces or states.

The Canadian Standards Association (CSA) developed a standard for Motor Vehicles for the Transportation of Physically Disabled Persons, CAN3-D409-M84. (Ref. 4). This standard details specifications for the vehicle chassis, vehicle body, wheelchair securement, occupant restraint system, wheelchair lift and service ramp of vehicles used for the transportation of the disabled. It specifies that wheelchair seating should be forward or rearward facing and that for each designated wheelchair position there must be a wheelchair securement and passenger restraint system. The Ontario government adopted the standard as regulation 167/81 under the Highway Traffic Act (Ref. 5). This is the most complete implementation of D409 of any Canadian province. The Manitoba government has enacted specialized transportation standards modelled after D409, but which are not a full implementation of D409.

At present, the remaining provinces have not enacted any specific legislation concerning specialized transportation vehicles. However, most provinces use CSA D409 as an advisory guideline for vehicle fabrication and inspection of existing vehicles. Also, many provinces anticipate adopting CSA D409 into legislation related to vehicles for the transportation for the disabled.

All vehicles sold in Canada are required by law to comply with Canadian Motor Vehicle Standards (CMVSS) 208, 209 and 210 for seatbelt installations, assemblies and anchorages, respectively (Ref. 6). The aforementioned CSA standard stipulates that wheelchair securement devices must comply with the above CMVSS standards. Transport Canada has derived from these CMVSS

standards, that a wheelchair securement system must withstand a 20g (g = acceleration due to gravity) frontal impact.

A Draft Guideline Specification for Wheelchair Securement Devices was reviewed at the National Workshop on Bus/Wheelchair Accessibility in Seattle Washington, May 1986 (Ref. 7). This guideline specifies technical requirements of wheelchair securement and occupant restraint systems, as well as the testing, certification and maintenance of the securement device.

2.1.5 Human Factors

Vehicle Operators

The following list outlines the responsibilities of the operator of a transportation service for the disabled:

- driving the vehicle and considering the special needs of the passengers being carried,
- manoeuvring wheelchair passengers outside of the vehicle (eg. tipping, lifting wheelchair over curbs).
- manoeuvring the wheelchair passenger inside the vehicle to the designated position,
- securing the wheelchair properly,
- assisting in emergencies that may arise,
- understanding and operating the technical equipment (eg. lift, restraint system), and
- understanding passenger characteristics and handling of the passenger with respect and dignity.

Wheelchair Users

The following describes the wheelchair users' disabling conditions. The main disabilities causing the need for a wheelchair are:

- Arthritis - inflammation of the joints often resulting in difficulty in walking - using hands and arms is painful
- Multiple Sclerosis - nervous disorder resulting in limited sensations
  - paralysis affects different parts of the body
- Paralysis - Quadraplegic - little or no control of upper and lower limbs
  - Paraplegic - little or no control of lower limbs
  - Hemiplegic - partial or no control of one side of the body.

The wheelchair passenger usually requires the assistance of the operator in securing the wheelchair and applying the passenger restraint. However, the users of sports chairs who are generally younger, athletic persons with complete control over their wheelchair and its manoeuvrability require very little assistance. Motorized wheelchair users can usually position themselves in the designated area with only minimal guidance from the operator, but may require the assistance of the operator in securing the wheelchair and attaching the passenger restraint.

The wheelchair user should perceive the designated area as a comfortable and pleasant environment. The securement system should not intimidate the passenger, but rather be seen as both physical and psychological protection.

Passengers, especially women, do not like the physical contact or closeness of the operator, particularly in the areas of the chest, hips, and lower limbs. Ride quality is perceived as no wheelchair movement during acceleration, braking and cornering of the vehicle.

A considerable number of the passengers transported by specialized vehicles are not using wheelchairs; walkers, crutches and canes are quite common. These passengers require only a seat and a storage space for their mobility aids. Therefore, for efficient operation of the vehicle, it is necessary to provide moveable seating in the areas where the wheelchair securement systems are located. In this fashion, zero seat loss may be obtained when no wheelchair passenger is using a wheelchair station. These passengers, however, often require a wider seat, with a pivoting armrest and support handles as well as more space in front of their seat.

2.2 EVALUATION CRITERIA

Evaluation criteria for a wheelchair securement system are essentially determined by legislation and/or adopted regulations. The criteria presented here were established from a thorough review and analysis of the material in Section 2.1 of this report.

An evaluation matrix of criterion versus score was developed and is presented in Table 2. It has been presented for the generic securement systems currently available, in order that the desirable and undesirable features of the different models could be determined and the results used in the development of concepts. The evaluation matrix was later utilized to analyze the new concepts and ideas for an improved wheelchair securement and occupant restraint system in Section 2.3.

2.3 DEVELOPMENT OF CONCEPTUAL DESIGNS

This section of the report highlights the development of the conceptual designs for the wheelchair securement/occupant restraint system by T E S Limited and Rutenberg Design Inc.

An analysis of the generic types of securement system, including T-bars, rod and hook, wheel or rim locks and floor mounted locking devices, revealed shortcomings in their ability to accommodate all wheelchair types, and in their general operation, occupant safety and reductions in vehicle capacity. These shortcomings were detailed in the weighted technical evaluation matrix outlined in Table 2. For the reasons above, these types of securement systems were eliminated from further considerations in the development of the design concepts.

Belt systems proved to have positive applications as shown in the technical evaluation matrix and were considered the prime candidate in the concept development.

In the analysis of the points on wheelchairs to which the securement system may be suitably attached, the structure of the wheelchair types and access to the attachment points were examined. For the first group of wheelchairs, which included standard manual, standard electric and sport chairs, common areas of attachment were identified as follows:

TABLE 2

Evaluation Criteria

PERFORMANCE (Weighting)	REQUIREMENT (Weighting)	GENERIC WHEELCHAIR SECUREMENT SYSTEM						CONCEPT	
		Belts	T-Bar	Rod and Hook	Wheel/ Rim Lock	Floor Mounted Device	Other (Multi Modal)	1	2
OVERALL SAFETY (50)	Wheelchair Securement								
	Limited Movement (20)	18	2	2	10	10	18	18	17
	Wheelchairs Accommodated (10)	9	3	3	6	6	6	9	8
	Passenger Restraint								
	Lap Belt (15)	10	1	4	4	4	14	14	14
	Torso Belt (5)	4	1	2	2	1	4	4	4
CONVENIENCE FOR OPERATOR (30)	Ease of Use (10)	5	3	2	8	3	5	8	6
	Minimum Securement Time (8)	5	2	1	7	2	6	7	5
	Minimum Operator Requirements (5)	2	1	1	4	1	3	4	3
	Wheelchairs Accommodated (4)	3	1	1	2	2	2	3	3
	Storage When Not In Use (3)	2	1	1	2	1	1	1	1
CONVENIENCE FOR USER (20)	Minimal Chair Movement (10)	9	1	1	5	5	9	9	8
	Minimal Damage to Chair (6)	4	3	3	1	2	1	4	4
	Minimal Physical Contact (4)	1	2	1	3	1	2	3	3
TOTAL SCORE (maximum of 100)		72	21	22	54	38	71	84	76

- the rear vertical frame tubes between the push handles and the centreline of the rear wheels, and
- the lower front frame section supporting the front wheels and footrest tubes.

The potential attachment points for the second group of wheelchairs, represented by the three wheel scooter, were found to be the platform frames, and not the seat/seat columns or the steering column.

Based on the foregoing examination of wheelchair types, securement systems and attachment points, as well as user, operator and technical requirements, a number of design concepts were developed.

Evaluation of their technical and operational features revealed that the following concepts best suited the overall requirements.

- Concept 1) Front and Rear Belts
- Concept 2) Rear Grip

Concept 1

Concept 1, shown in Figure 3, is a system of retractable belts/hooks which secures the wheelchair to the floor at four points. The belts are stored inside a floor mounted structure which also contains the tensioning mechanism. The passenger restraint is provided by retractable lap (and torso) belts. This securement system may be used in any bus or van model and adapts to many wheelchair types as shown in Figure 4. If several wheelchairs are secured in a line, only one floor mounted structure needs to be installed between each wheelchair position since the front support structure for one wheelchair serves as the rear support structure of the wheelchair directly in front. The floor mounted structures may also be rotated against the vehicle wall for storage.

The driver/attendant manoeuvres the wheelchair adjacent to the designated wheelchair position. The rear harness (Item 1) and retractable front belts (Item 2) are attached to the wheelchair frame. The front belts will automatically retract as the wheelchair is manoeuvred into the designated area. They are then locked using a lever (Item 3). The retractable rear belt (Item 4) is spooled out, attached to the rear harness (Item 1) and then tensioned using a ratchet lever (Item 5). The aisle side lap belt (Item 6) is passed beneath the wheelchair armrests and fastened into the buckle. (The retractable torso belt (Item 7) is positioned across the passenger's upper body, beneath the outside armrest and fastened onto the lap belt).

Concept 2

Concept 2, shown in Figure 5, utilizes two independent systems to secure the front and rear of a wheelchair. The rear securement consists of two adjustable telescopic arms connected to a floor mounted structure. These arms are free to pivot and swivel with length adjustment provided by a simple pin/hole mechanism.

The front securement consists of a padded crossbar which is placed horizontally over the front of the lower horizontal wheelchair frame and is

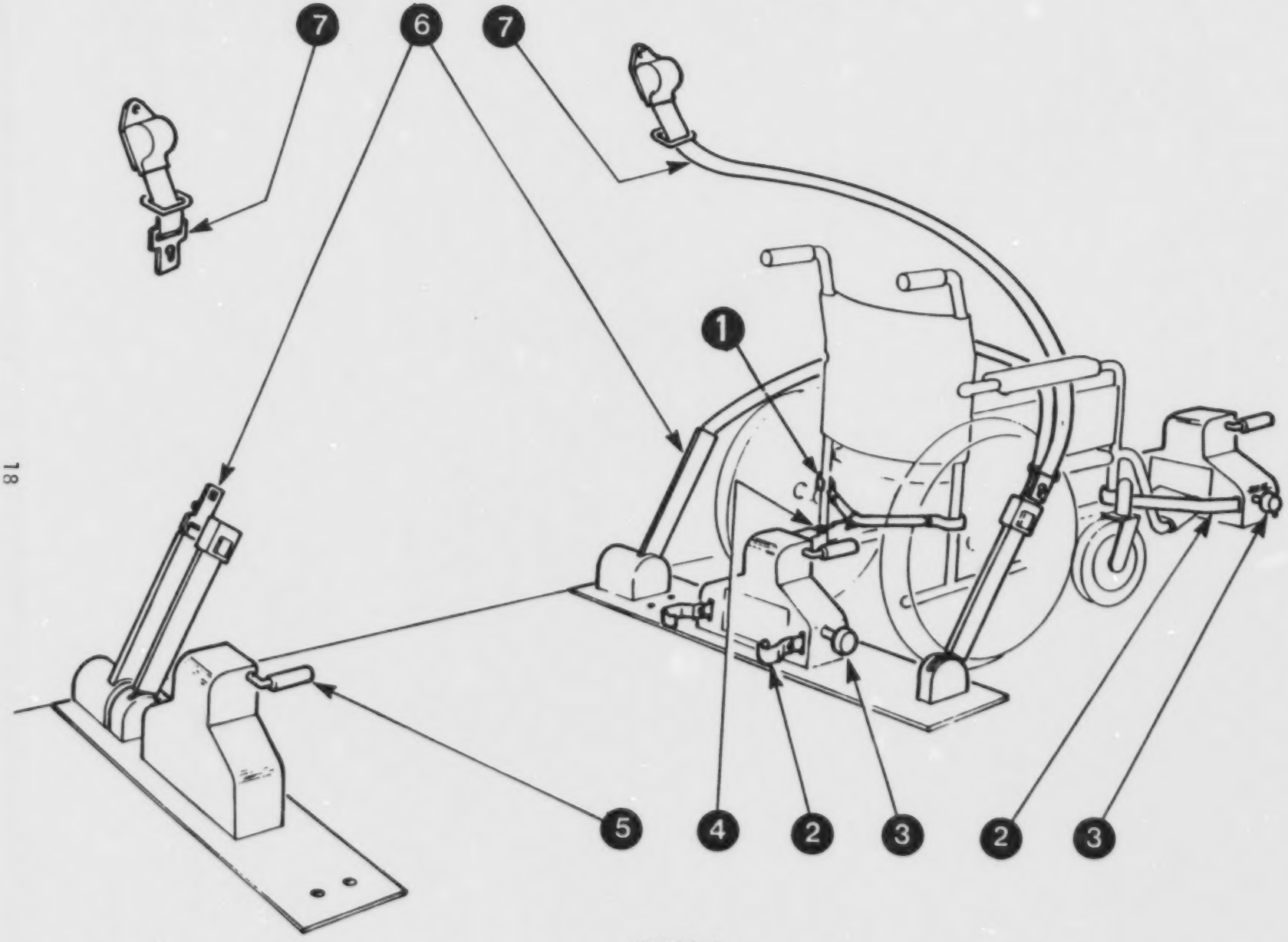
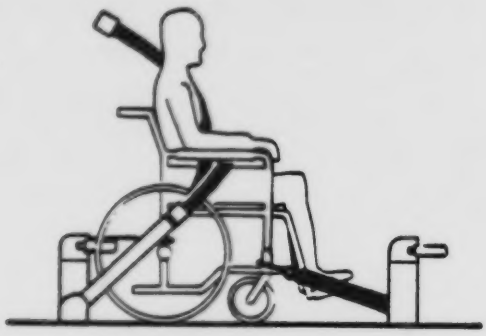
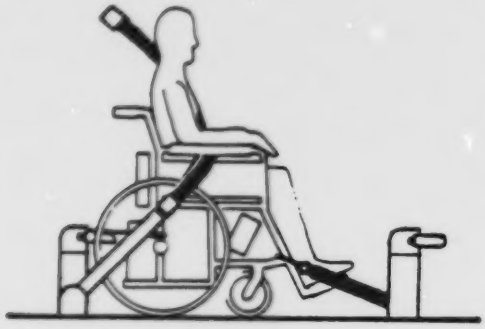


FIGURE 3

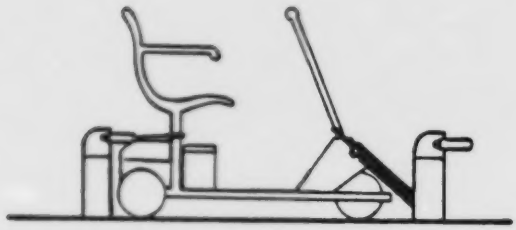
General View - Concept 1



Standard Manual

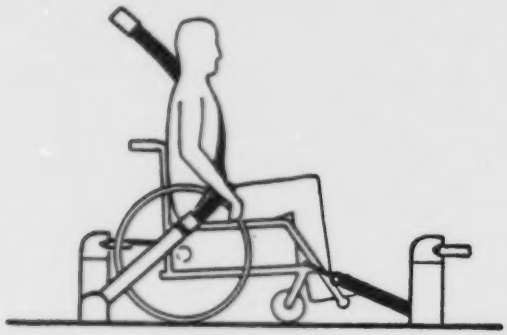


Standard Electric



Scooter

Note: Passenger is transferred to an adjacent ambulatory seat and the scooter is secured.



Sport Chair

FIGURE 4

Wheelchairs Accommodated - Concept 1

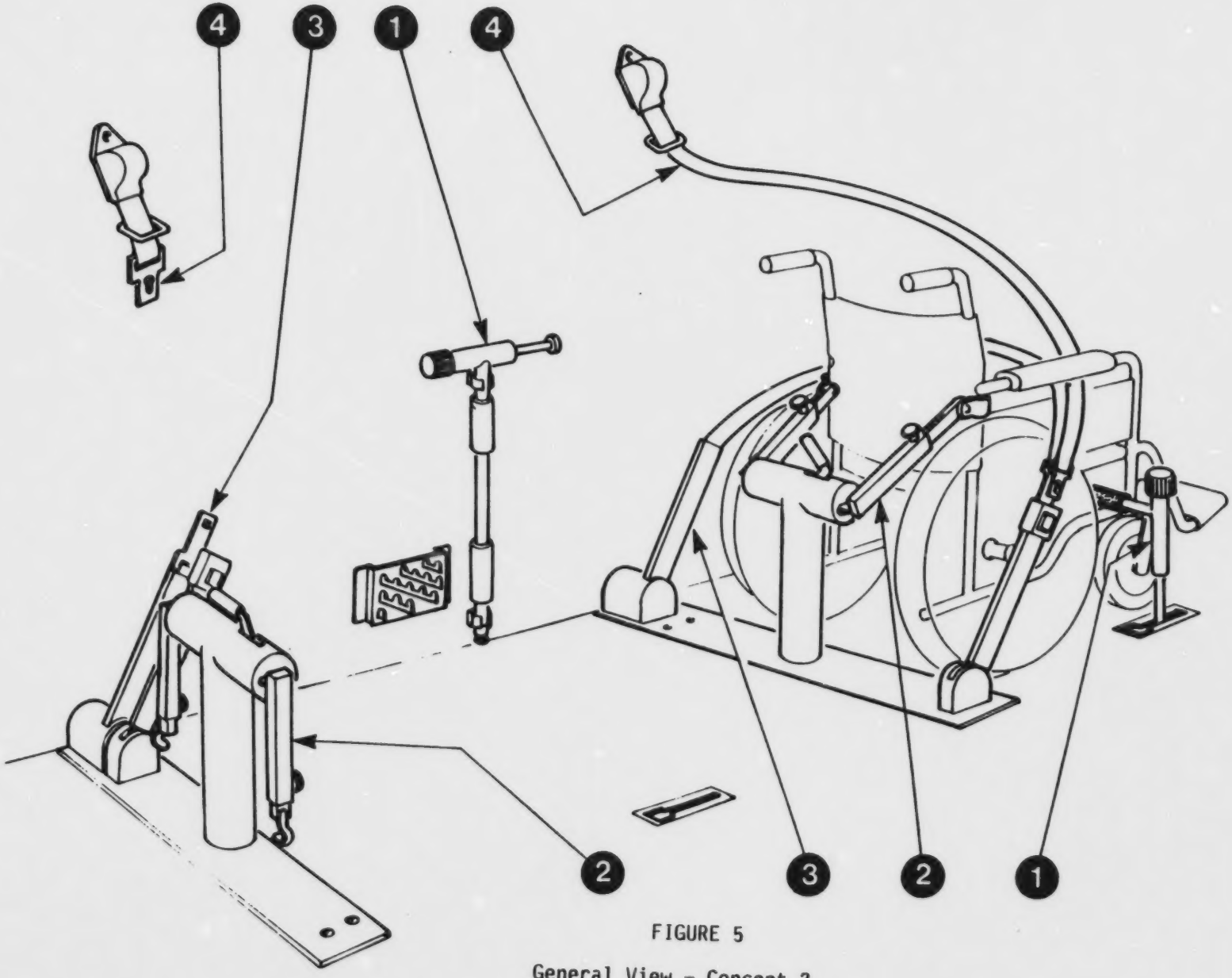


FIGURE 5

General View - Concept 2

held in place on the vehicle wall and the aisle side vehicle floor. This cross bar may be supplied as a telescopic unit to reduce the lateral space required for deployment. The passenger is positioned facing the direction of travel and occupant restraint is provided by retractable lap and torso belts. The securement system may be used in any bus or van model and adapts to most wheelchair types as shown in Figure 6.

The driver/attendant manoeuvres the wheelchair into the designated area. The front securement bar (Item 1) is positioned horizontally, securing the lower front frame of the wheelchair, using the wall anchor tracks and the aisle side floor channel. The wall tracks and floor channel allow horizontal and vertical adjustment of the front securement bar to ensure fitment and adequate down-force to various wheelchair frames. The rear telescopic arms (Item 2) are attached to the rear vertical tubes of the wheelchair, immediately above or below the armrests, and locked into place. The retractable lap (and torso) belts are deployed and fastened in the same manner as in Concept 1.

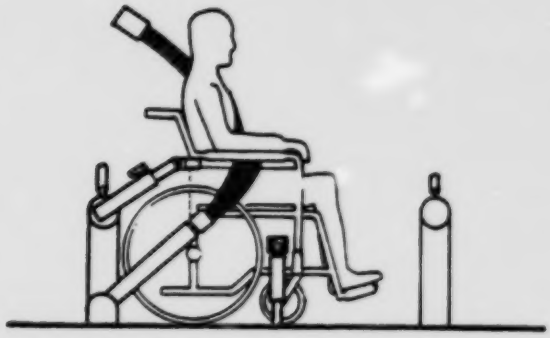
2.4 EVALUATION

The two concepts were evaluated using the criteria previously developed for other generic system types outlined in Section 2.2. The evaluation results are summarized in Table 3 and clearly show the merits of the new concepts. One must bear in mind that the results of the evaluation are quite subjective, particularly for the new concepts, since no actual units exist for evaluation purposes. The relative performance of current systems were evaluated and reported to TDC during the first stage of this project. For the new concepts, the evaluation results were derived from our understanding of the specific operational features of the concept, when visualized in a production state. Thus, the evaluation results for the new concepts are more subjective than results for other systems (currently being manufactured). We have attempted to be as realistic as possible in our evaluation, however, given the inherent subjectivity of the process.

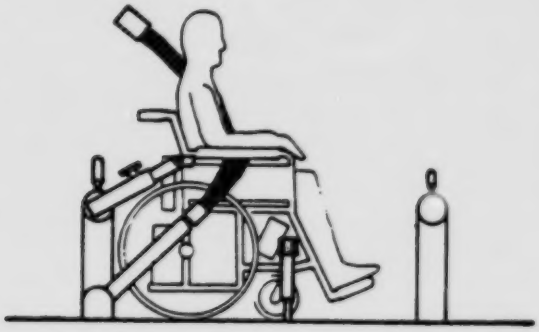
Overall, Concept 1 was ranked significantly better than Concept 2 which, in turn, was superior to other generic systems although only slightly better than "Belts" or "Other" (MultiModal) systems. In terms of overall safety, both concepts were ranked quite close, although only marginally improved over the "Belts" or "Other" systems.

The evaluation also showed Concept 1 to be superior to Concept 2 in terms of convenience for the operator and user, although the difference is almost insignificant in the latter case. The major advantage of Concept 1 over Concept 2 is the ease of use, securement time and operator requirements. These factors result primarily from the use of belts which offer three dimensional attachment flexibility unparalleled by other techniques. In addition, the retracting and tensioning features of the belts in Concept 1 provide very fast and simple installation and securement. Other systems such as the "Wheel/Rim Lock" offered convenience to the operator similar to Concept 1, however, the performance in other areas was found to be far inferior.

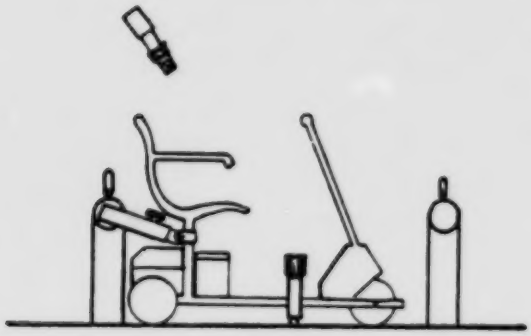
In summary, Concept 1 was evaluated as the most promising concept for further development. It obtained the highest overall evaluation score by a



Standard Manual

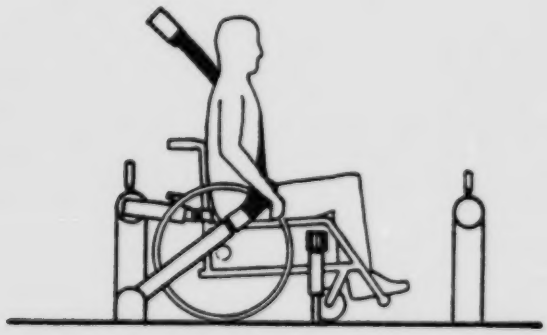


Standard Electric



Scooter

Note: Passenger is transferred to an adjacent ambulatory seat and the scooter is secured.



Sport Chair

FIGURE 6

Wheelchairs Accommodated - Concept 2

TABLE 3

Weighted Technical Evaluation Matrix

PERFORMANCE (Weighting)	REQUIREMENT (Weighting)	GENERIC WHEELCHAIR SECUREMENT SYSTEM						CONCEPT	
		Belts	T-Bar	Rod and Hook	Wheel/ Rim Lock	Floor Mounted Device	Other (Multi Modal)	1	2
OVERALL SAFETY (50)	Wheelchair Securement								
	Limited Movement (20)	18	2	2	10	10	18	18	17
	Wheelchairs Accommodated (10)	9	3	3	6	6	6	9	8
	Passenger Restraint								
	Lap Belt (15)	10	1	4	4	4	14	14	14
	Torso Belt (5)	4	1	2	2	1	4	4	4
CONVENIENCE FOR OPERATOR (30)	Ease of Use (10)	5	3	2	8	3	5	8	6
	Minimum Securement Time (8)	5	2	1	7	2	6	7	5
	Minimum Operator Requirements (5)	2	1	1	4	1	3	4	3
	Wheelchairs Accommodated (4)	3	1	1	2	2	2	3	3
	Storage When Not In Use (3)	2	1	1	2	1	1	1	1
CONVENIENCE FOR USER (20)	Minimal Chair Movement (10)	9	1	1	5	5	9	9	8
	Minimal Damage to Chair (6)	4	3	3	1	2	1	4	4
	Minimal Physical Contact (4)	1	2	1	3	1	2	3	3
TOTAL SCORE (maximum of 100)		72	21	22	54	38	71	84	76

margin of approximately 10% over Concept 2 and 17% over the best of the current systems (Belts). Concept 1 was not found to have tremendous advantages over other systems in all categories. Rather, the major design objective of the concept which appears to have been successful, was to utilize the knowledge of other systems and create a solution which provides a good compromise. The anticipated performance of Concept 1 in all areas of concern is only equal or slightly better than any other specific system. It offers an optimized solution to a complex problem by satisfying the complete spectrum of performance with no particularly weak or strong areas.

2.5 USER SURVEY

A nationwide survey was undertaken by SYPHER:MUELLER Associates Ltd. to estimate the marketability of the Concepts 1 and 2. Their report appears as Appendix "D" and this section of the report highlights their findings.

The survey consisted of a questionnaire accompanied by drawings and descriptions of the concepts. This package was mailed to various operators of transportation services for the disabled across Canada and to one operator in the United States. The operators were asked to evaluate each system including their existing system in terms of a variety of operational, psychological, safety and ergonomic criteria. To simplify the process of completing the questionnaire, and to maximize the response rate, most questions were phrased to be answered in point form. The English and French questionnaires appear in Appendix "D". This Appendix also contains further details regarding the structure of the questionnaire and lists the operators to whom the questionnaires were sent.

The questionnaire was well received, with several operators expending considerable effort to complete the questionnaire, and most responses showed considerable thought and care. Also, the 23 responses corresponded to a response rate of 51% which was considered outstanding in an exercise of this nature.

Respondents were found to employ a wide range of wheelchair securement/passenger restraint devices including "Weco", "Q-Straint" and various devices designed and manufactured in-house.

The major findings of the questionnaire survey are as follows:

- Existing devices are considered satisfactory in most regards, but are viewed as being deficient in the areas of emergency release mechanisms and accommodation of scooters.

- Operators tend to be unreceptive to the new concepts, and tend to prefer their existing systems.

- Concept 1 is generally viewed as being superior to Concept 2 by the operators.

- Operators did not consider purchase price and installation costs as a very important factor in their decision process as compared to maintenance costs and operation time costs.

- The new devices are not expected to have a major impact on the operation of transportation systems for the disabled as a result of more efficient operations, greater numbers of passengers carried, etc.

2.6 FEASIBILITY OF PHASE 2

The purpose of this section of the report is to assess the pros and cons upon which the decision to proceed with Phase 2 was based. This objective was achieved by examining the findings/comments from the user survey discussed in Section 2.5.

Table 4 summarizes the operators' assessements of Concepts 1 and 2 with respect to existing devices. At first glance, it appears that the new concepts show limited merit. However, the high response rate and meticulous comments provided by many operators suggest a strong interest in the whole area of wheelchair securement and passenger restraint.

From Table 4, it can be seen that both Concepts 1 and 2 were viewed as being deficient compared to existing devices in the areas of comfort/personal dignity, ease of use and ease of installation and maintenance. Discussions with the operators indicated their strong operational and pragmatic focus. They relate more closely to day-to-day issues and tangible measures of performance rather than abstractions. Asking the operators to compare descriptions and drawings of hypothetical concepts to systems currently owned and in use is placing the former at a severe disadvantage. A respondent is unlikely to classify any aspect of a device presented in this manner as "excellent", and is likely to lean towards the undue rejection of the new concepts and the mistaken retention of the status-quo, rather than an unwarranted decision to reject existing systems. A more accurate test-marketing process would include presenting potential purchasers with actual prototypes and mockups, with viewpoints collected by direct interview.

From Table 4, it is clear that operators viewed Concept 1 as being better than their existing systems in accommodating a variety of wheelchairs including scooters. This fulfills a very important requirement of a securement system.

Data from Table 4 also shows that the operators surveyed did not consider purchase price and installation costs as playing a very important role in their decisions regarding the new systems as compared to maintenance costs and operation time costs. Those operators interested in purchasing the new systems would prefer a gradual phase-in of these devices. It would appear that they have no strong aversion to running a mixed fleet, but would value the opportunity to test the new devices alongside the old. Even those operators who have chosen to remain with existing devices might welcome the opportunity to participate in the test program.

The user survey also revealed a significantly more favourable response to Concept 1 rather than Concept 2. This is again reflected in the results shown in Table 3.

In light of our previous research and thorough review of the results of the user survey, T E S Limited recommended that Concept 1 be further developed and demonstrated during Phase 2 of the project. It was believed that Concept 1 could prove to be a short term solution to the securement/restraint

TABLE 4

Assessment of Concepts with Respect to Existing Devices

Assessment Factors	Concept 1	Concept 2
Technical		
Passenger comfort/dignity	-	-
Ease of use	-	-
Ease of installation	-	-
Ease of maintenance	-	-
Accommodate all wheelchairs	+	-
Accommodate scooters	+	+
Emergency release	+	-
Economic		
Purchase price	0	0
Installation costs	0	0
Operating efficiency	0	0

LEGEND

+ better than existing devices
- worse than existing devices
0 indifferent

problems currently experienced by operators of transportation services for the disabled and could provide improved ergonomic and operational advantages over current belt systems.

It was our opinion that many of the negative responses and most of the additional comments from the respondents stemmed from an unclear understanding of the concepts. Many of the concerns would be resolved from an examination of an actual prototype unit. Several comments were highly justified and would be considered during the design stage. One such concern is that the size and manoeuvrability of the securement unit allow interior configurations which can be quickly and easily changed. This consideration should maintain a high level of space utilization at all times and allow reasonable entry/exit clearance paths which are most critical in smaller vehicles. Information of this nature and its relative importance to different operators was very beneficial at this stage, prior to the detailed design.

Following a review meeting with TDC, it was decided that the project should proceed with the design, fabrication and evaluation of a prototype of Concept 1.

3. PHASE 2 - DETAILED DESIGN AND PROTOTYPE CONSTRUCTION, DEMONSTRATION AND EVALUATION OF PERFORMANCE

This section of the report describes Phase 2 work of this project. The detailed design and mockup were prepared by Rutenberg Design Inc. The fabrication and evaluation of the prototype were performed by T E S Limited. Delcan Corporation organized the in-service evaluation program.

3.1 DETAILED DESIGN

This segment of the report outlines the detailed design methodology for the optimum conceptual design, Concept 1.

The primary objective of the detailed design was to provide a device which would alleviate the ergonomic problems associated with current belt type securement/restraint systems (as identified in Section 2.5), while at the same time attaining the performance level of current belt systems. In particular, the device was designed to be easier for the operator to use.

Standard automotive belt retractors were used to provide a three point attachment system (two at the front and a Y-attachment at the rear). Retractors offer many advantages including belt stowage, ready accessibility for deployment, and freedom to retract in and pay out as the wheelchair is being fitted with the belts. The retractors were contained in housings, for both front and rear securement. The housings were designed such that the side wall end of the housing was a pivot and the inboard end was rotatable both fore and aft towards the sidewall. This feature was achieved by a latch mechanism press fitted to mate with a pivot floor plate, and a roller in the outboard end to assist the operator. This feature was necessary to provide the required clearance between adjacent wheelchair positions to allow for wheelchairs to access the aisle.

The central post on the housing was equipped with quarter turn locking/unlocking devices for both sets of retractors (front and rear). This post was designed to reduce the physical effort of performing the locking/unlocking task.

A retractor for a lap belt was positioned on a tall stalk for easy access by both the operator and the passenger.

Wherever possible, standard materials, finishes and specifications, and commonly available hardware and production techniques were used to ensure acceptance by manufacturers and operators.

Technical drawings (for the components and assemblies) including a parts list and material specifications were prepared by Rutenberg Design Inc. The drawings depicted a combined unit which consists of both front and rear securement of the wheelchair. In addition, a full mock-up of the concept was constructed. The intent of the mock-up was to provide a true representation of the design such that actual volumes, controls and component finishes could be assessed along with the development of the detailed design.

3.2 PROTOTYPE FABRICATION AND EVALUATION

The prototype was fabricated according to the drawing package developed during the detailed design stage of this project.

Although the drawing package illustrates a combined unit which provides components for both front and rear securement (such that more than one wheelchair can be secured in a row), the prototype shown in Figure 7 consisted of a front unit and rear unit for a single wheelchair position. In addition, operational procedures, storage details and installation instructions were prepared for the prototype as shown in Appendix "E".

While the prototype was being fabricated, an in-service demonstration program was organized. Two Ottawa area operators, Blue Line Taxi who operates Para-Transpo on a contract basis for OC Transpo, and Travelways which operates a school charter service, agreed to participate in the demonstration of the prototype wheelchair securement device. These operators represented a wide range in operating services (e.g. charter, contract, parallel types) and a range in vehicle types (e.g. vans, small buses and intercity buses).

The purpose of the in-service evaluation was to obtain comments from driver/operators regarding the installation, operation and maintenance of the prototype and to solicit comments from wheelchair passengers.

Following the fabrication of the prototype, it was mounted onto a fixed surface for an in-house evaluation. This evaluation consisted of securing various wheelchairs using the prototype, and then assessing its operation.

The results of this evaluation identified two major problems: tightening the single Y-attachment at the rear tended to cause a folding wheelchair to fold inwards on itself, and, the vertical down force was insufficient to hold the wheelchair as firmly as other common belt type systems.

Prior to any modifications, the prototype was then installed by Para-Transpo into an Orion II bus. Deficiencies in the installation and operation were as follows: the correct alignment between the pivot floor plate and the mating portion of the securement unit was difficult; the operator may not notice whether or not the floor latch lever is fully engaged and; the two problems found during the in-house evaluation were again noted.

Two of these deficiencies were not serious and were corrected relatively easily. The alignment between the pivot floor plate and the mating portion of the securement, although difficult, was possible. The actuation of the floor latch lever was modified such that there were only two possible positions, either engaged or disengaged. Each position was readily observable.

The other two problems, however, required major modifications. The rear Y-attachment proved to be undesirable, particularly when securing a foldable wheelchair. As a result, the prototype was modified to provide two retractable belts on the rear securement unit, similar to that of the front unit, as shown in Figure 8. This modification eliminated the collapsing of the wheelchair, however, the vertical hold down force was still insufficient. The forces generated by a four point belt system, such as the "Q'Straint",

(Y-ATTACHMENT AT REAR)

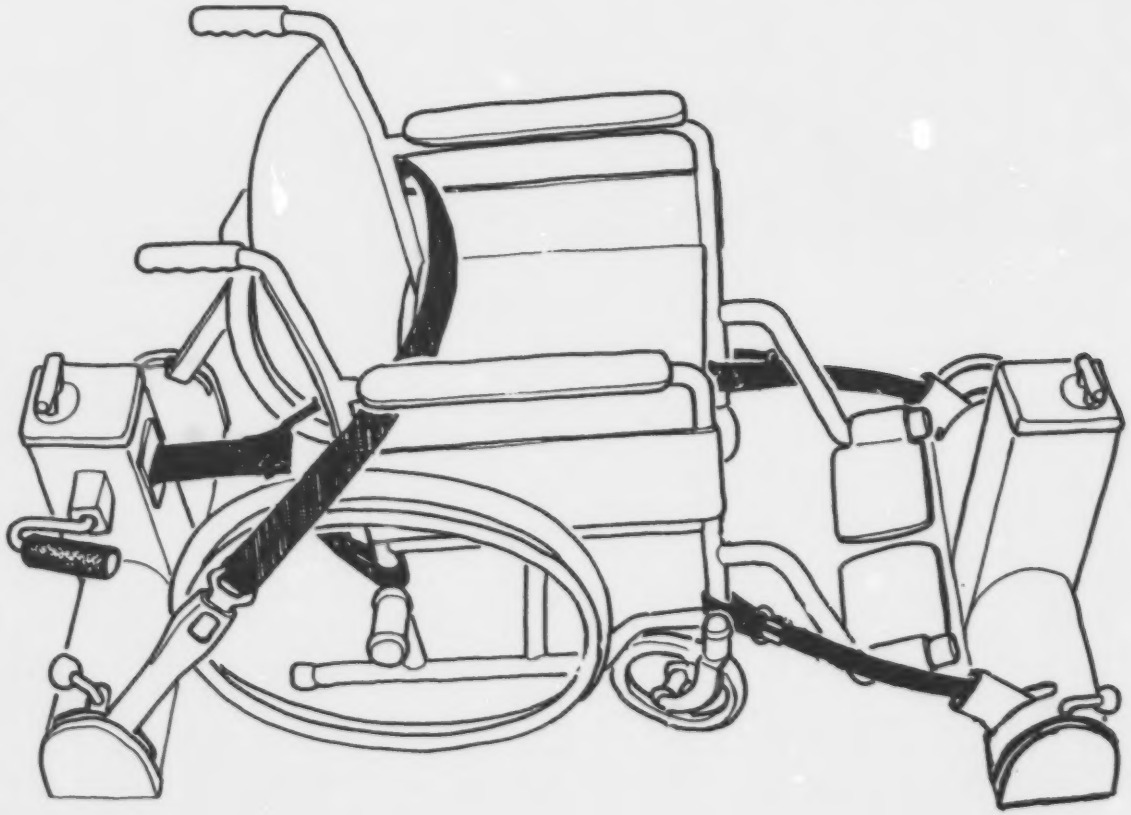


FIGURE 7

Original Version of Prototype

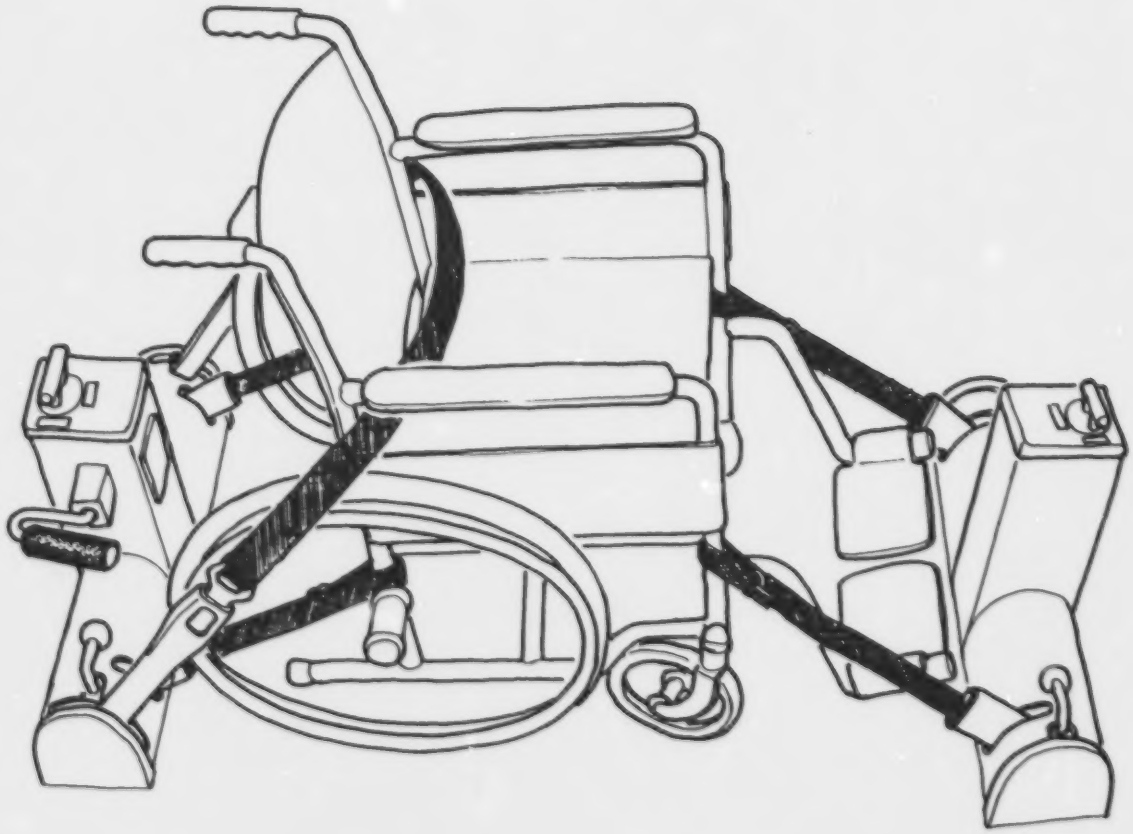


FIGURE 8

Modified Version of Prototype

were compared to the forces generated by the modified prototype, to determine the cause of the degraded performance. It was found that the lateral distance between the belts was not as important as the longitudinal distance between the belts. As the longitudinal spacing is increased from that of the "Q'Straint", the vertical down force decreases since the belt angle goes away from the vertical. The longitudinal spacing for the modified prototype was thus reduced to the minimum, which would still accommodate a standard wheelchair. The spacing of the "Q'Straint" was still not attainable however, because the securement housing limits how closely you can position the front and rear units. Any attempt to reduce the longitudinal spacing further would create interference between the housing and the wheelchair, and require extra effort by the operator.

Although the prototype demonstrated the advantages of retractable belts and pivoting bulkhead, it was determined that any further modifications to the prototype would eliminate the desirable ergonomic design features. Also, further modifications would create a more complex device (and hence be more costly). It was anticipated that these drawbacks would result in operator reluctance to use the system.

4. CONCLUSIONS

The decision to proceed from concept to Phase 2 of the project was based on the premise that the selected concept would alleviate the ergonomic problems associated with current belt type restraint/securement systems. Although this appeared to be the case with the design as presented, evaluation of the prototype indicated that securement system performance had been downgraded in the process. Attempts to modify the design in order to restore the down force capability to the level currently achieved by belt type systems had the effect of negating the improved ergonomic features. Therefore, it was agreed that the demonstration program should not be completed.

This project, as well as others conducted for TDC, concerning the transport of wheelchairs and passengers in accessible modes of transportation, has thus reinforced several opinions.

The results of this project have demonstrated that a four-point belt system is the most suitable type of device to adapt to a wide variety of wheelchairs (with the "Q'Straint" being the most popular in Canada). Belt systems which meet CSA Standard D409 and the Transport Canada 20g frontal impact requirement should be considered as a technical and cost effective interim measure for securing wheelchairs in accessible transportation.

5. RECOMMENDATIONS

A further improvement to the existing four-point belt system would be to permanently mount attachment anchors onto wheelchairs to provide easier and quicker securement. This type of modification is being investigated by the International Standards Organization, (ISO), the Ministry of Transportation of Ontario (MOT) and a Canadian wheelchair manufacturer, Fortress Scientific.

The obvious long term solution to the overall wheelchair securement problem lies in the standardization of the interface between the wheelchair and the transporting vehicle.

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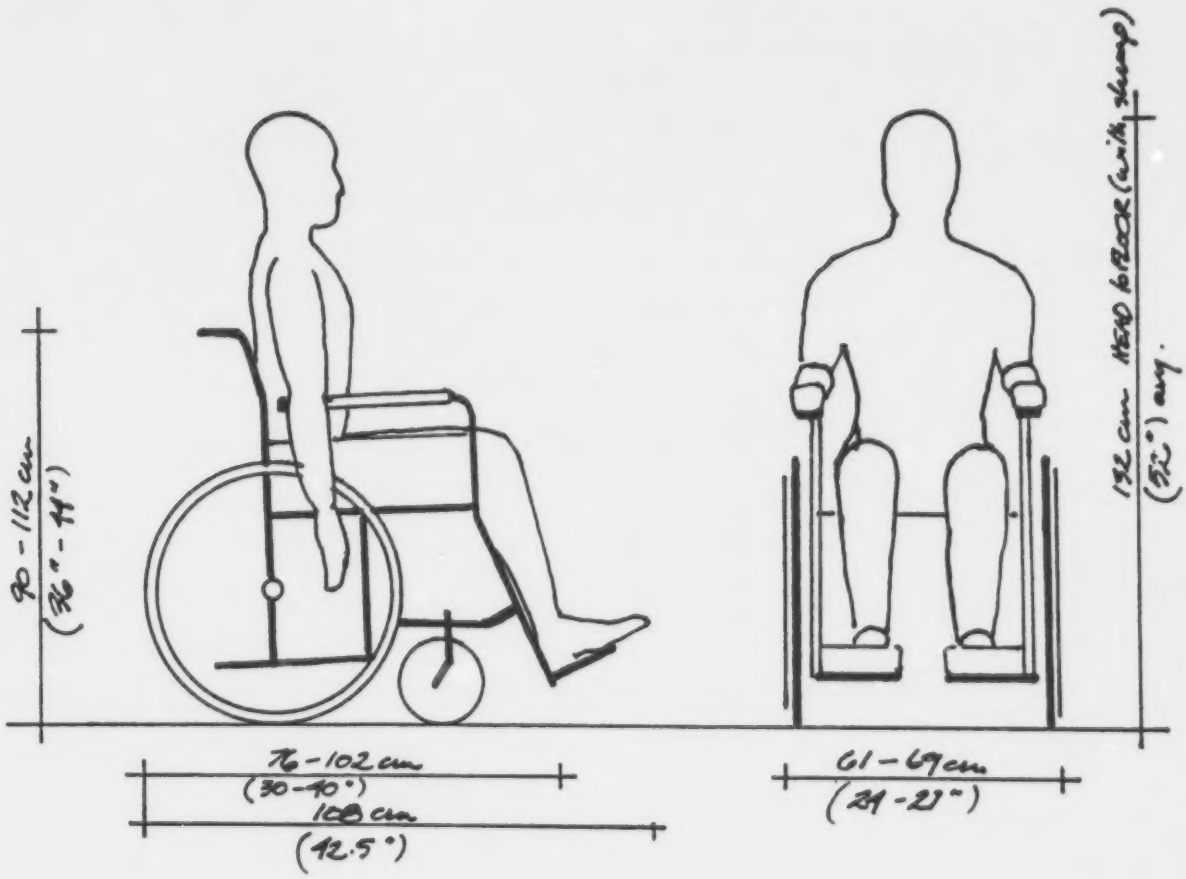
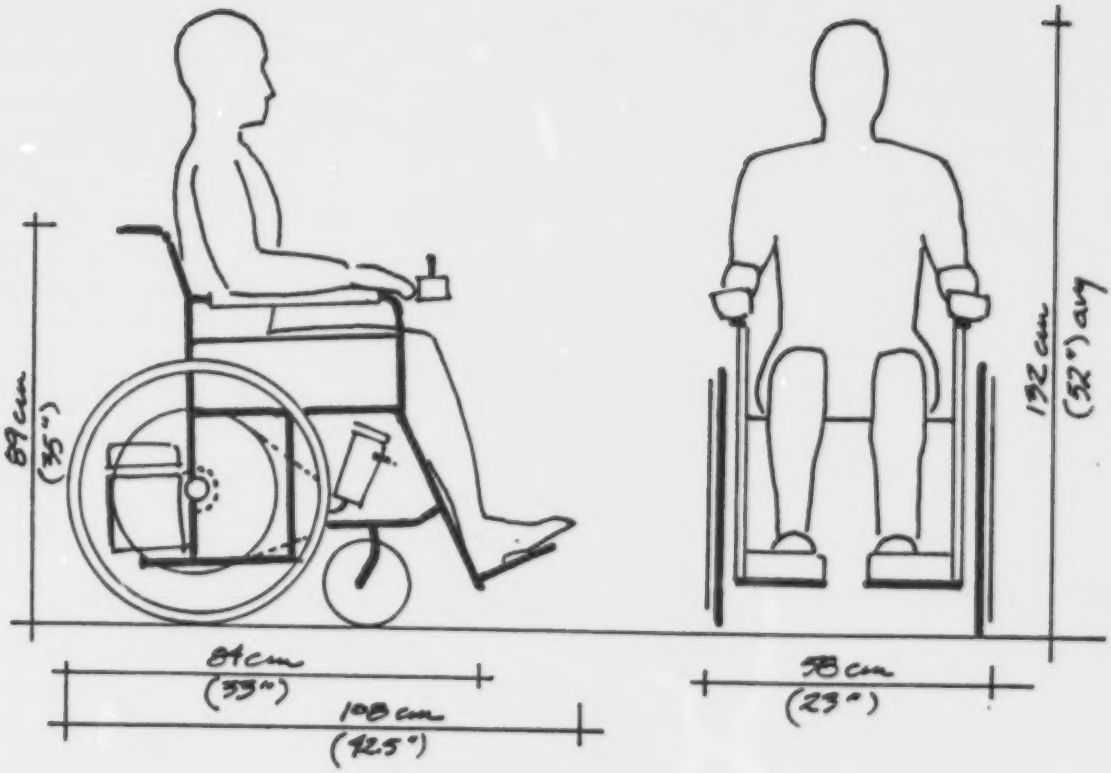
APPENDICES

APPENDIX "A"

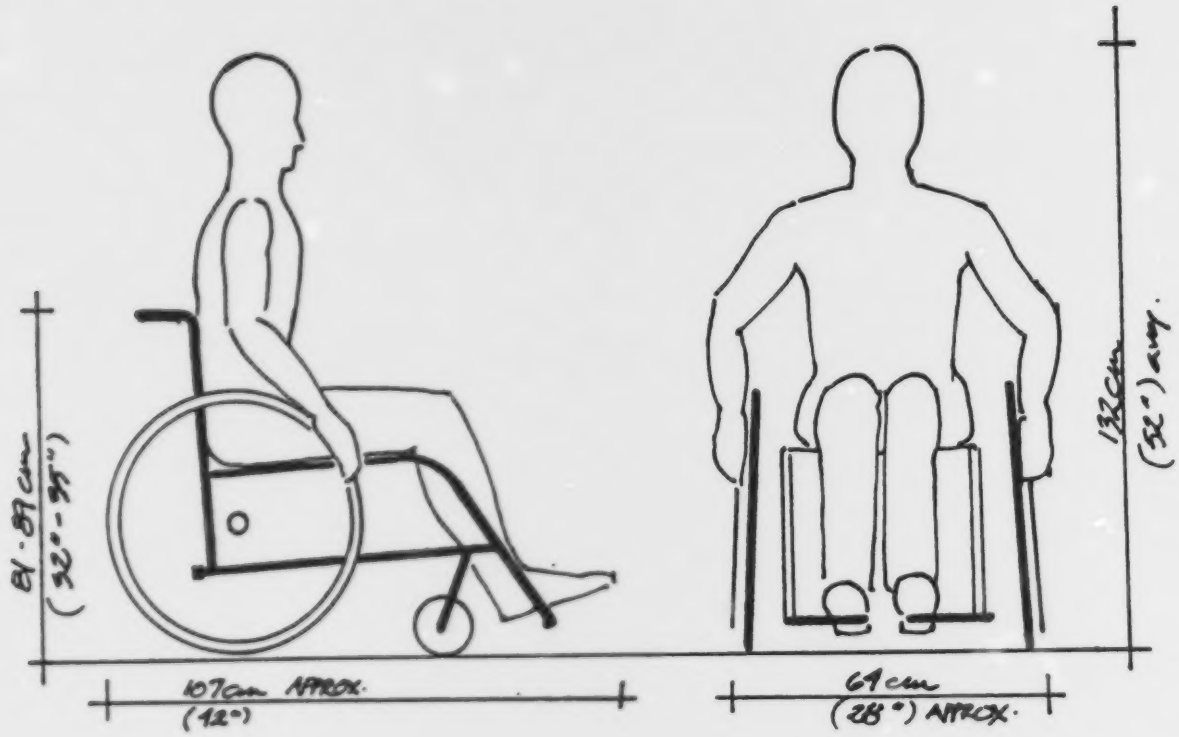
Wheelchairs



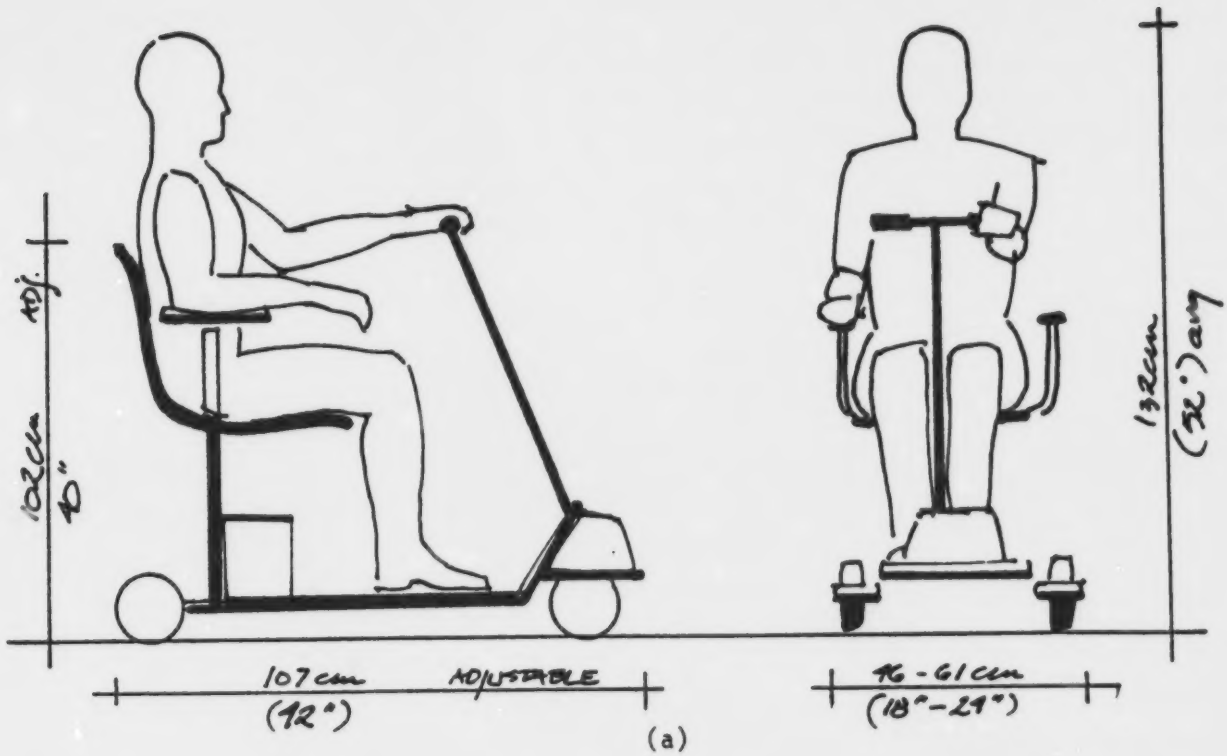
Standard Manual Wheelchair



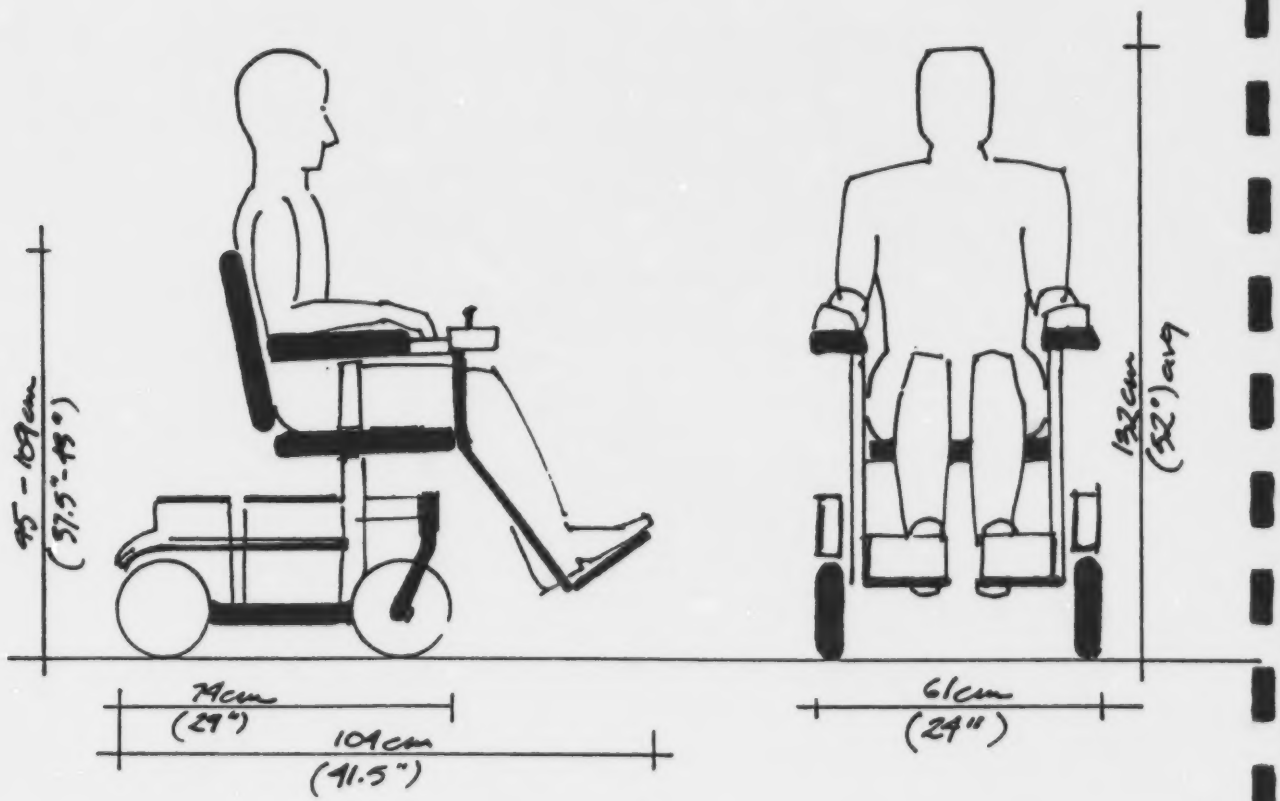
Standard Electric Wheelchair



Standard Manual Sport Chair



(a)



(b)

3 Wheeled Scooters (a) and
and 4 Wheeled Non-Conventional Chairs (b)

Manufacturer or Distributor	Model	Type				Wheelchair Specifications					
		1	2	3	4	Height (cm)	Width (cm)	Length (cm)	Wheel Diameter Rear (cm)	Wheel Diameter Front (cm)	Weight (Kg)
Neil & Bennett	Motorized Chair				x	-	-	-	20	20	-
A-BEC	40				x	94	62	102	30	20	48
	41				x	99	62	102	30	20	48
	46				x	121	62	119	30	20	49
	47				x	132	62	122	30	20	49
	14,15,17,18				x	96	57	94	20	20	38
	Scoota			x		-	61	112	20	20	47
Fortress Scientific	655 FS Deluxe				x	109	61	105	25	25	46
	650 FS				x	104	61	117	25	25	64
	2000 FS			x		-	61	107	-	-	49
Everest & Jennings	Mobie			x		-	61	97	20	20	45
Ortho - Kinetics	Lark			x		-	66	105	22	22	49
	Outsider Power chair				x	-	-	-	-	-	-
Summit Service	Elevating Chair				x	-	-	-	-	-	-
Alpha	Tri-Kart-Standard			x		-	46	99	15	15	31
	Youth			x		-	-	-	15	15	-
	Heavy Duty			x		-	61	-	15	15	-
Amigo	Amigo			x		-	61	99	15	15	27
Invacare	Rolls Run-about (Dart)			x		-	80	120	20	20	57
Everest & Jennings	Premier	x				91	63	78	61	20	20
	O.C. Flyer				x	91	59	91	25	25	47
	12 UVE 924SV				x	239	73	118	30	51	62
	Traveller	x				-	67	-	61	20	-

1 Standard Manual
2 Standard Electric
3 3 Wheeled Chair
4 4 Wheeled Chair

Summary of Commercially Available Wheelchairs

Manufacturer or Distributor	Model	Type				Wheelchair Specifications					
		1	2	3	4	Height (cm)	Width (cm)	Length (cm)	Wheel Diameter		Weight (kg)
									Rear (cm)	Front (cm)	
W.A. Thompson & Co.	8,3b, Self Tourer, 3,4	x				93	69	104	61	18	24
	Attendent Tourer, 9	?				94	65	93	32	19	18
	Terrier	x				73	57	76	51	13	21
Braun	Tri-wheeled			x		91	64	97	25	22	92
Fortress Scientific	2200FS			x		-	72	104	-	20	45
	755FS				x	-	61	67	20	20	45
Oetho-Kinetics Ltd.	Sierra			x		84	55	118	25	25	69
	Pony 11			x		76	71	104	-	20	-
	Bravo			x		-	46	102	15	15	36
	Colt			x		86	70	122	25	25	69
	Martin 601, Katrin 611	x				99	56	64	46	8	10
	Swede	x				86	69	94	61	13	14
Ortho-Kinetics	Care Chair 111	x				-	51	80	20	13	-
	Travel Chair 6302					-	43	80	20	13	-
	Travel Chair 6332					-	51	84	20	13	-

1 Standard Manual
2 Standard Electric
3 3 Wheeled Chair
4 4 Wheeled Chair

Summary of Commercially Available Wheelchairs

Manufacturer or Distributor	Model	Type				Wheelchair Specifications					
		1	2	3	4	Height (cm)	Width (cm)	Length (cm)	Wheel Diameter Rear (cm)	Wheel Diameter Front (cm)	Weight (kg)
Theradyne	Starliner	x				-	67	-	61	20	-
	Power chairs		x			-	64	-	51	20	37
	Envoy	x	x			-	81	-	61	20	-
	Venture					-	81	-	61	20	-
	Maxim	x				-	-	-	61	20	-
Canadian Wheelchair mfg	Voyageur	x				88	66	81	61	20	19
	Voy. Recliner	x				113	66	91	61	20	20
	Laurentian	x				105	66	93	61	20	18
	Horizon	x				91	62	81	61	20	16
Vessa	Vitesse			x		103	66	99	30	18	66
	Travvla			x		93	64	100	30	18	56
	Flivva				x	98	64	120	13	20	53
	Variant	x				144	70	114	61	19	23
Invacare	Power Rolls IV		x			95	66	84	51	20	82
	Sportstra	x				-	-	-	61	13	12
Everest & Jennings	Utralight Premer	x				-	-	-	-	-	-
Remploy	8 LJ	x				97	58	107	56	19	18
	8 BL	x				93	64	89	51	13	15
I D C Tectonics	L C4, L C5		x			135	58	114	61	20	45
Quadra	Rigid	x				107	61	71	68	10	11
	Fold	x				102	61	72	68	10	13
	Esprit, Carrera Sprint, tour	x				104	-	-	68	10	10
Motion Designs	Quickie	x				121	66	89	66	13	11
Precision Wheelchairs	Rigid, Collapsible, Economy	x				-	-	-	-	13	11

1 Standard Manual
2 Standard Electric
3 3 Wheeled Chair
4 4 Wheeled Chair

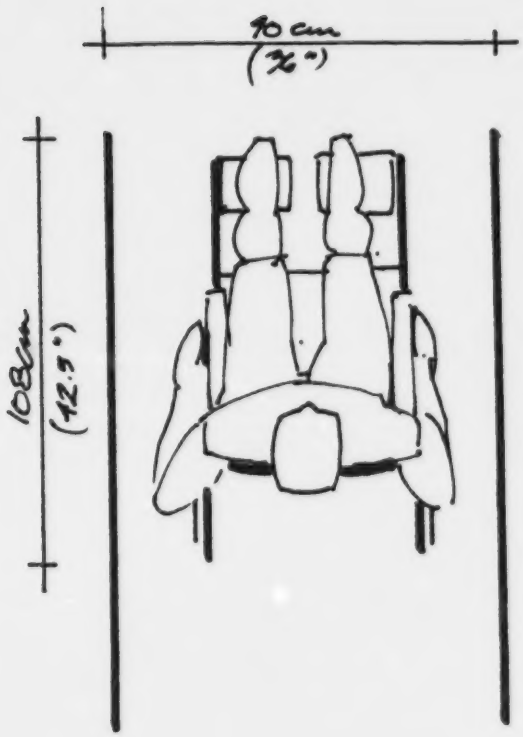
Summary of Commercially Available Wheelchairs

Generic Type of Wheelchair	Height (cm)	Width (cm)	Length (cm)	Wheel Diameter (cm)		Weight (kg)
				Front	Rear	
Standard Manual	73.0-144.8	56.9-81.3	53.3-106.7	12.7-25.4	38.1-61.0	10.0-22.7
Standard Electric	81.2-144.8	50.8-68.6	76.2-114.3	12.7-20.3	50.8-61.0	36.3-80.6
3 Wheeled Electric	76.2-101.8	45.7-71.1	91.4-121.9	15.2-30.5	15.2-30.5	86.2-92.1
4 Wheeled Electric	94.0-119.4	61.0-71.1	91.4-121.9	20.3-50.8	20.3-50.8	38.1-62.1

Summary of Wheelchair Specifications

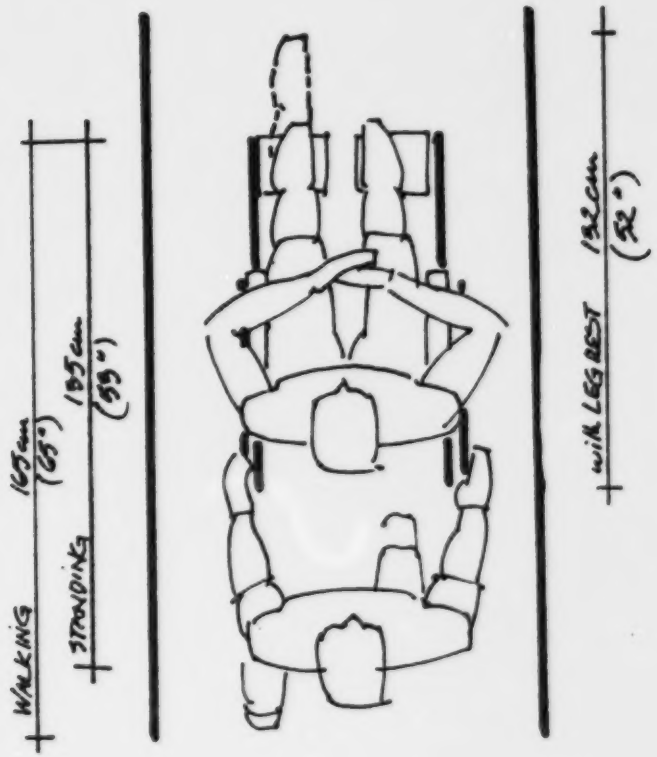
WHEELCHAIR CIRCULATION SPACES

Straight line movement - standard manual



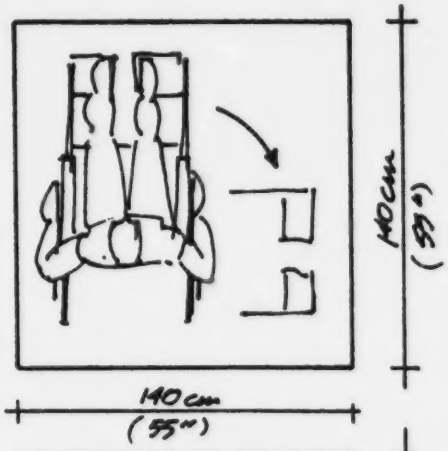
- self-propelled wheelchair.
- more space is required for projecting elbows.
- severely handicapped, a more erratic course.
- minimum clearance of 5 cm (2") is required between any obstruction and the wheelchair when maneuvering.
- experienced wheelchair users can confidently maneuver with only 1 cm clearance.

Straight line movement with operator

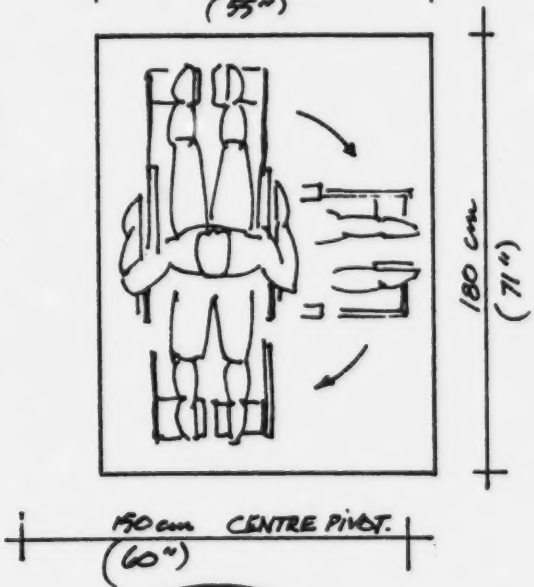


- extreme case to be considered
- wheelchair user with leg rest
- foot rest extension, add 51 cm (14½").

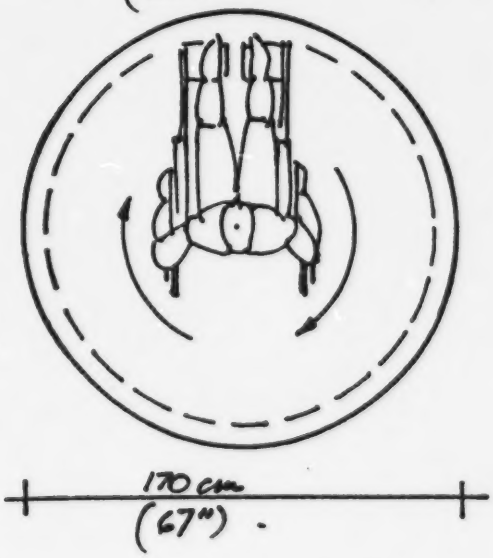
Turning spaces - Manual wheelchairs



SPACE for 90° TURN

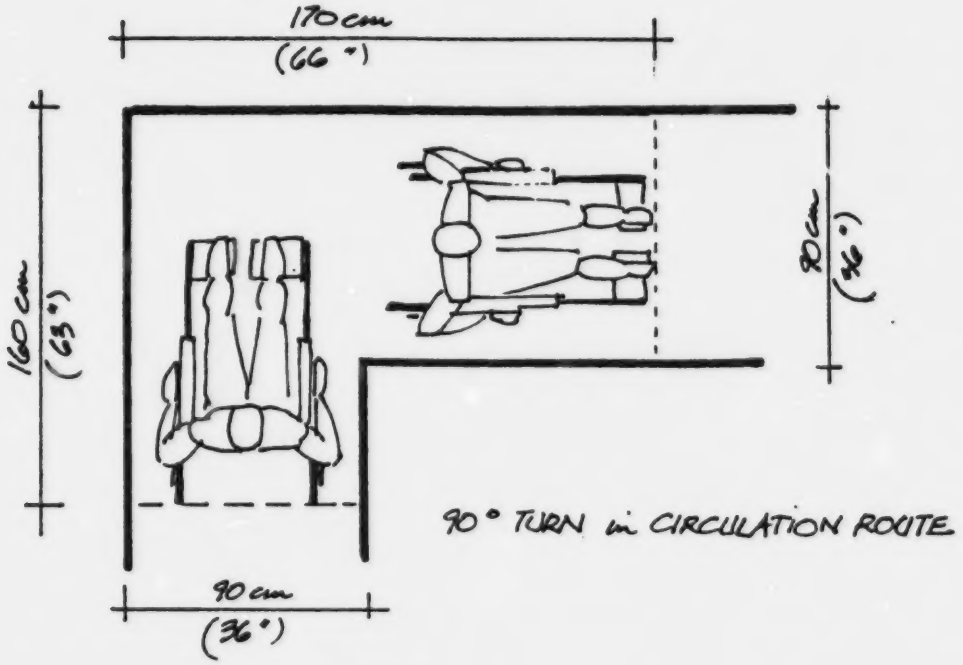


SPACE for 180° TURN

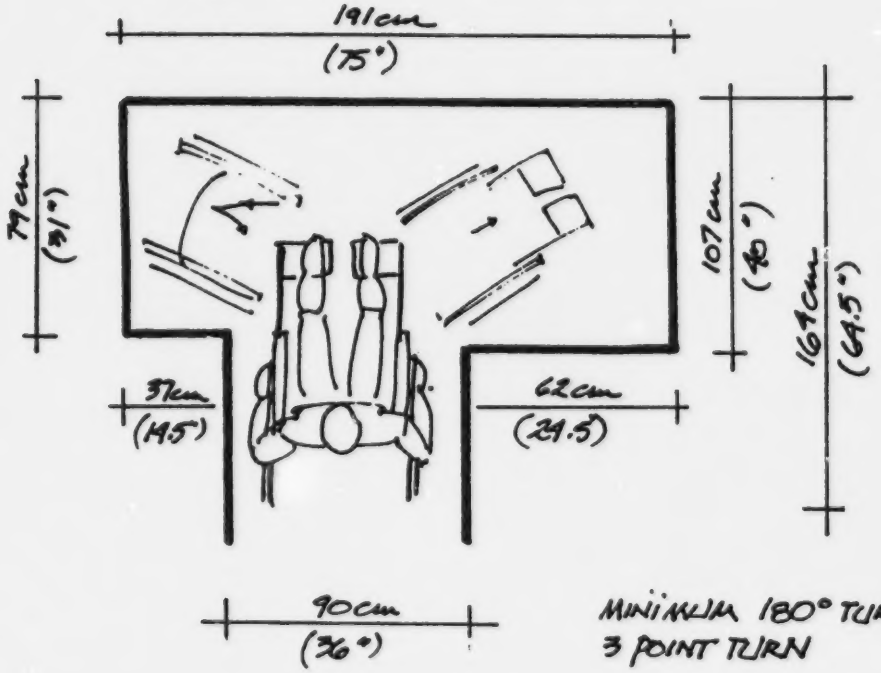


UNOBSTRUCTED SPACE for 360° TURN

Turning spaces - Manual wheelchairs

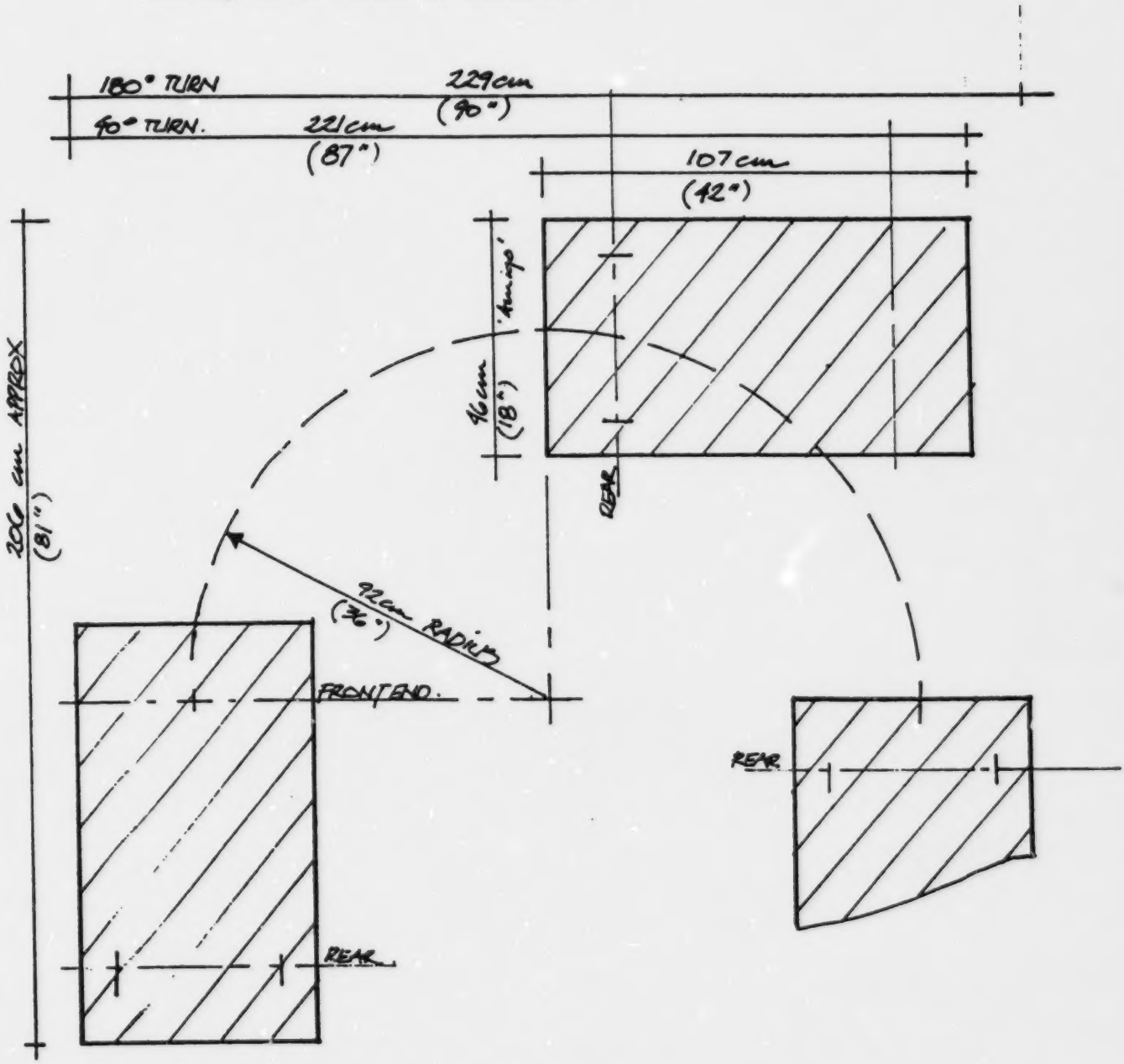


90° TURN in CIRCULATION ROUTE



MINIMUM 180° TURN
3 POINT TURN

Turning radius - Electric wheelchair



3-wheeled chairs - turning radius

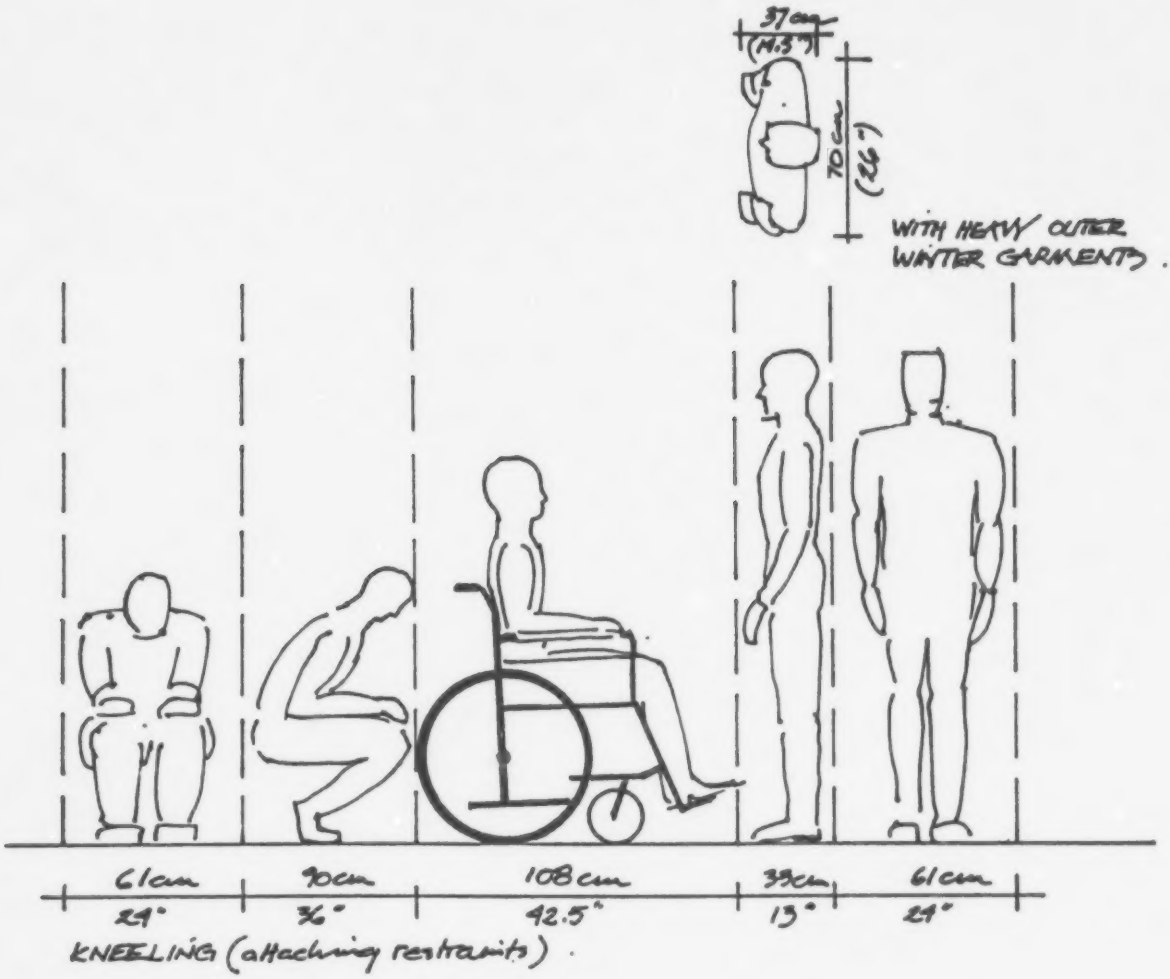
Amigo - 92 cm 36")

Fortress - 102 cm (40")

4-wheeled chairs - turning radius

Fortress - 76 cm (30")

Space requirements for operator around wheelchair



- allowable working space required for operator to apply wheelchair and occupant restraints.

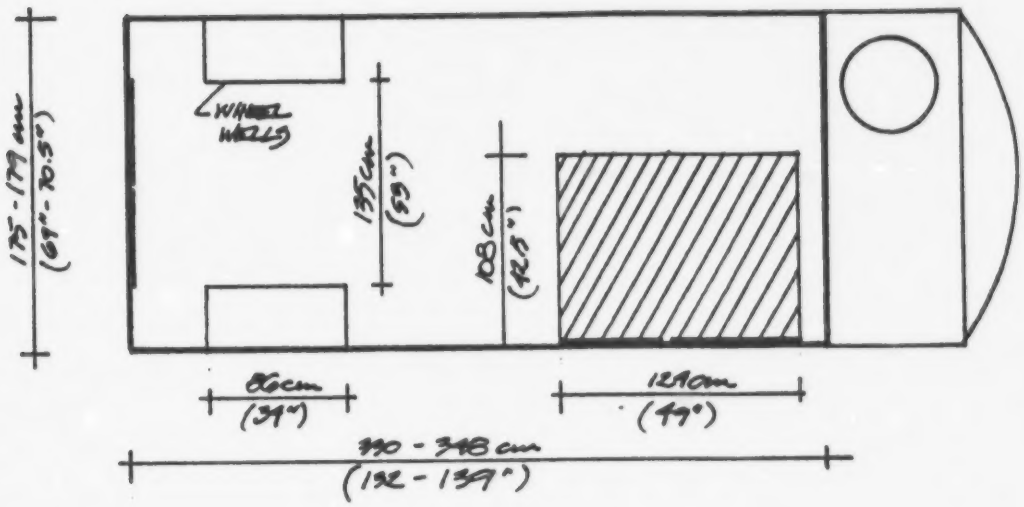
APPENDIX "B"

Specialized Vehicles

Classification of Specialized Vehicles	Wheelbase (m)	Overall Height (m)	Overall Width (m)	Overall Length (m)
Standard Van Conversions	3.0-3.5	1.5-3.0	1.8-2.2	4.5-5.8
Body on Chassis	3.2-7.0	2.6-3.2	2.0-2.5	4.7-12.0
Bus Conversions				
a) Small	3.8-4.3	3.0-3.2	2.4-2.5	9.0-11.0
b) Large	6.5-7.0	2.7-3.0	2.2-2.5	11.8-12.2
Custom Built (Orion II)	6.1	2.5	2.4	7.8

Specifications for Specialized Vehicles

Standard Van Conversions



- floor space availability
  - interior dimensions

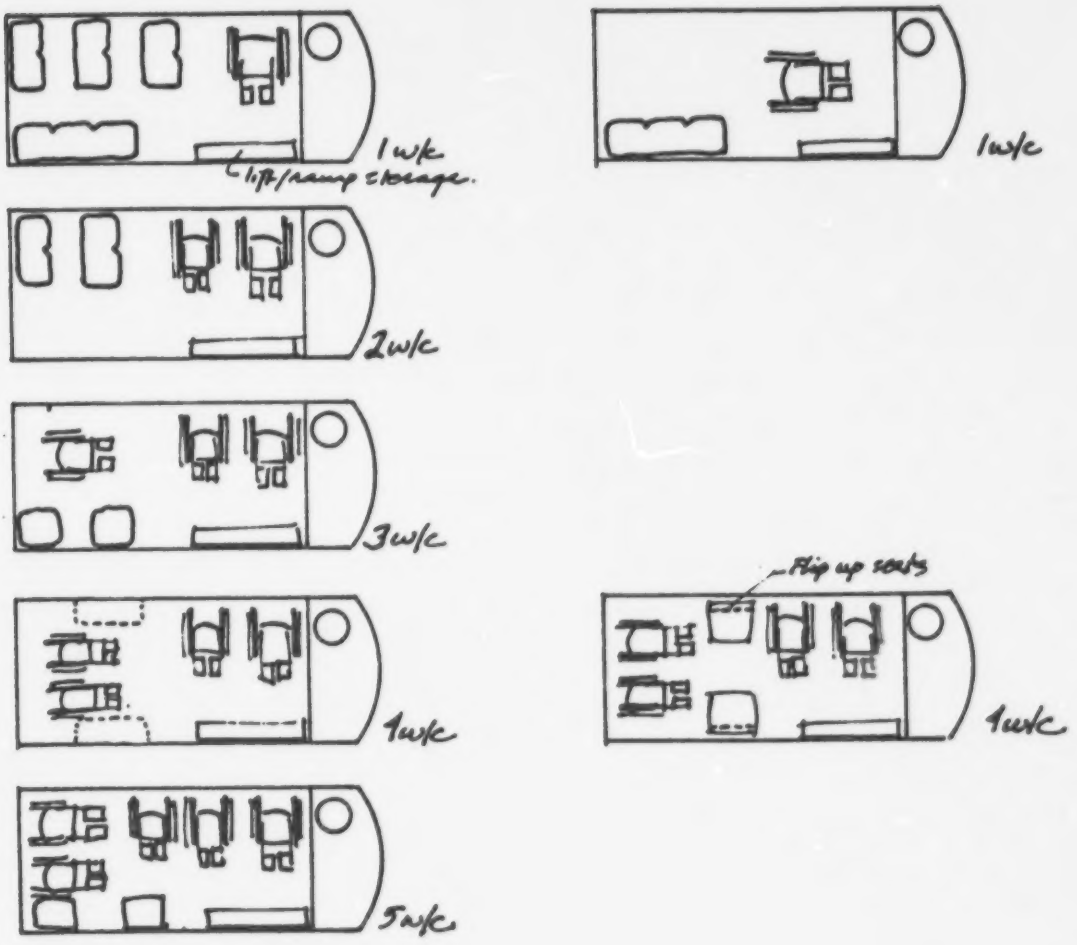
width	-	1.75 m - 1.79 m
length	-	3.33 m - 3.48 m
headroom	-	1.27 - 1.35 min.
		1.91 - 1.98 max. (with raised roof)

- wheelchair lift/ramp access is curbside, in front of rear wheel.

- alternative access - front door
  - rear double doors.

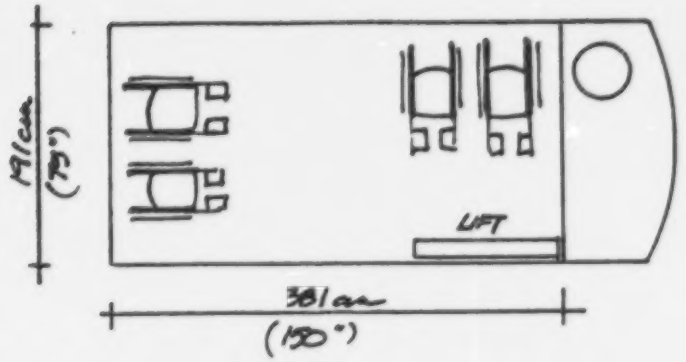
Standard Van Conversions

Interior layout - commom positions for wheelchair spaces.

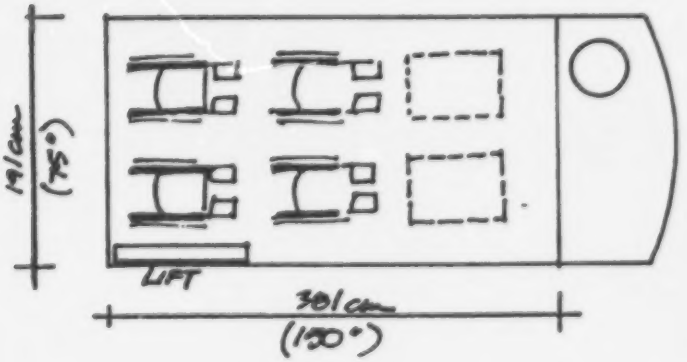


- vans have smallest floor space for maneuvering, inside width approximately 175 cm (70").
- some vans have low ceilings.
- floor obstructions, wheel wells.
- sloped walls.
- emergency exit - front door
  - rear double doors.
- first wheelchair is generally positioned sidewards behind drivers seat.

Body on Chassis



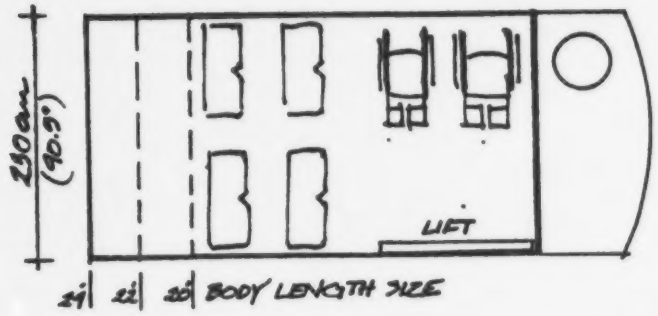
- wheelchair lift, curbside, front
- interior dimensions
  - width - 191 cm (75")
  - length - 381 cm (150")
  - headroom - 160-188 cm (63" - 74")



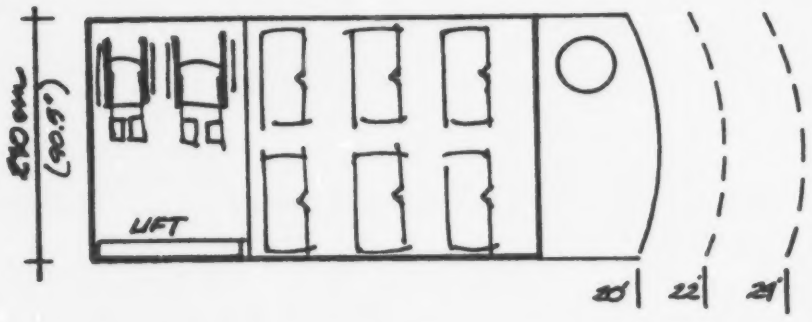
- wheelchair lift at rear, behind rear wheels.

Body on Chassis (wide body)

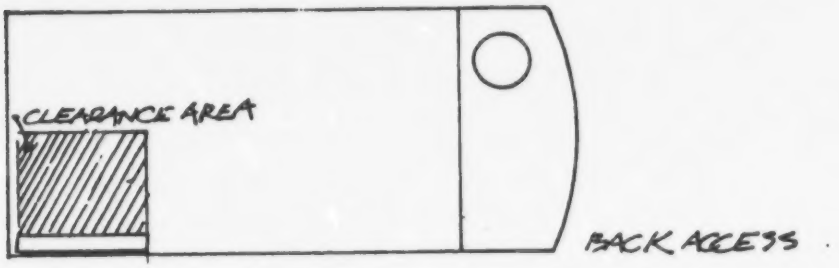
- 3/4 ton, usually 1 ton chassis
- platform and body built on chassis.



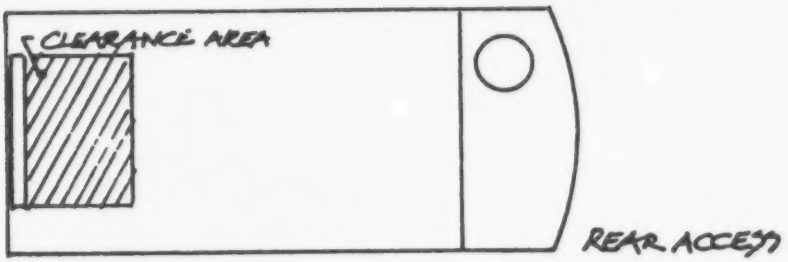
- front door, curbside, wheelchair lift
- interior dimensions
  - width - 230 cm (90.5") at seating height
  - headroom - 193 cm (76") centre asile.
- two wheelchair spaces, behind drivers seat.



- rear door left
- 2 wheelchair spaces provided only.



- most common location, on right side.
- boarding from sidewalk
- disadvantage, only one way parking on street otherwise dangerous boarding in traffic.



- rear boarding, better layout for wheelchair spaces.
- disadvantage is parking space required behind vehicle, wheelchairs must overcome curb.

Wheelchair Lift/Ramp Location

APPENDIX "C"

Securement Systems

62 Services Reporting

DEVICE	TYPE OF PASSENGER RESTRAINT AVAILABLE
4 pt systems:	
Q-Straint	FS
Belt & Track	F(2), FP(2), P, FPS
Thomas	F(2), P(2), FPS
Weco	FP(5)
No name	P(2)
Braun	FP, P
Rim Pin:	
Jump seat	F, J
Manual	F(5), P, FP(2)
Semi-automatic	P, W
T-Bar	P(3), F(2), FP
Home-made	P(4), F(2), FP
Belt Arm Wrap	P(2), F, W, FP
Cable & Hook	FP(2), P, F
Belt Wheel Wrap	P(2)
3 pt	P

( ) = number of services
W = wall mounted lap belt
F = floor mounted lap belt
P = personal torso belt
S = shoulder straps
N = none
J = jump seat frame mounted

Occupant Restraint Systems Used in Canada

APPENDIX "D"

User Survey

WHEELCHAIR SECUREMENT AND PASSENGER RESTRAINT SYSTEM

USER SURVEY

SYPHER:MUELLER International

November, 1987

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WHEELCHAIR SECUREMENT AND PASSENGER RESTRAINT SYSTEM -USER SURVEY

I. INTRODUCTION

Drawings and descriptions of the two concepts were mailed to potential users throughout Canada, as well as to one operator in the United States. Included with the descriptions was a questionnaire designed to estimate the marketability of the new devices. The purposes of the questionnaire were as follows:

- To determine, for each operator, the type of wheelchair securement/passenger restraint systems already in use.
- To determine the operator's degree of satisfaction with the existing devices; the perceived strengths and weaknesses of systems now in use.
- To determine the perceived strengths and weaknesses of the new concepts.
- To determine the operator's preferred system; the devices presently in use, Concept 1 or Concept 2.
- To determine the importance of the price of either Concept 1 or Concept 2 to the operator's preferred decision; that is, is the operator deterred from installing the concepts in the fleet by the purchase price?
- To determine total market demand for the concepts.
- To develop a profile of transit systems for the disabled, particularly those operators who express a desire to purchase the new devices.

The methodology was straightforward. Operators were queried on their views on both their existing systems and the two new concepts. They were asked to evaluate each in terms of a variety of operational, psychological, safety and ergonomic criteria, and their preferred choice for the future. They were then asked to furnish data on the number of systems actually required, and the purchase/phase-in schedule. A profile of the companies; total volumes, number of vehicles, and the portion of persons in wheelchairs, can then be used to estimate the market share of the new systems, and to establish any patterns or commonalities to operators who indicate a desire to purchase the systems.

II. QUESTIONNAIRE DESIGN

The English language questionnaire and covering letter are portrayed in Appendix 1 and the corresponding French translations are in Appendix 2.

In designing the questionnaire, the study team made extensive use of the study "Van Operator Survey - Wheelchair Securement Devices" by J.M Porter of the University of Waterloo. This survey highlights many of the problems encountered in existing systems, and has been used as a point of departure for the current project.

Each questionnaire package included a covering letter explaining the purpose of the project, the questionnaire itself, and detailed drawings/descriptions of the new concepts. Several drafts of the questionnaire were tested, with inputs from the Transportation Development Centre. Para Transpo, a division of OC Transpo, agreed to examine the questionnaire from the perspective of a respondent, and to suggest any ways in which the questionnaire could be made more relevant, clear and comprehensive. To simplify the process of completing the questionnaire, and to maximize the response rate, most questions were phrased to be answered in point form. In rating systems currently in use and the two concepts, respondents were asked to check "Excellent", "Acceptable" or "Unacceptable" boxes.

The questionnaire consists of four sections. Questions 1 and 2 identify the system the operator is presently using, and the degree of satisfaction in the following areas:

Comfort/personal dignity of passengers

This question examines the system in terms of its acceptability to passengers. The report "Van Operator Survey - Wheelchair Securement Devices" by J.M Porter of the University of Waterloo indicated that devices such as the Q-Straint was undignified and embarrassing for both the passenger and the operator.

Ease of Use for Drivers and Attendants

The Porter study indicated that most operators consider the deployment of their systems to be overly time-consuming. This increases overall transit times, lowers the quality of transportation services, and inhibits vehicle utilization.

Ease of Maintenance

According to the Porter study, problems have been encountered with dirt on floor-mounted components. Regular cleaning is required, particularly in winter. If the systems are designed for warmer climates, they might generally be ill-suited for Canadian winters. Some devices may pose specific maintenance problems.

Ease of Installing System on Vehicle

Some systems, while relatively inexpensive, may require a long or costly retrofit of the vehicle, thereby negating any up-front capital cost savings.

Ability to Accommodate Different Makes and Sizes of Wheelchairs

Wheelchairs can be purchased in a wide range of styles and sizes. The wheelchair securement/passenger restraint system must be sufficiently flexible to accommodate the vast majority of wheelchair designs.

Ability to Accommodate Scooters

The Porter study indicated a lack of uniformity in standards for the accommodation of scooters. Some operators refuse access to persons with scooters, others can accommodate some, but not all scooter makes, and others have no experience with scooters. Different operators using the same kind of device sometimes had widely disparate views about their abilitiy to accommodate scooters. In some situations, a scooter might be haphazardly tied down and the person transferred to a seat. Given the growing popularity of scooters among the disabled, the issue of scooter accommodation is of major importance in developing a satisfactory wheelchair device/passenger restraint system.

Emergency Release

This is a safety issue. It was included at the suggestion of Para Transpo.

The following criteria pertain to existing devices only. Without actual experience with the new devices, operators are not able to answer the following for the new devices:

Maintains Initial Settings - No Need to Check, Tighten or Readjust Fittings During Transportation

A system which needs continuous checking and adjustments during use is both an operational nuisance and a possible safety hazard. While the Porter study indicated that clear mechanical defects

and failures were unusual, operators might nevertheless feel required to inspect and readjust the devices more often than would otherwise be optimal. The answers to this question can be viewed as a proxy for the perceived reliability of the existing devices.

Availability of Spare Parts

A device may be relatively simple to maintain but only if specific, custom-made components are available. Lack of spare parts may either reduce the level of safety, require operators to maintain an expensive inventory of spares, or not utilize those positions on the vehicle whose securement devices lack essential parts.

Durability of System

The durability of the wheelchair securement/passenger restraint system may be of concern to operators through its impact on operating costs.

The second portion of the questionnaire, question 3, then explores operator reaction to each of the two new concepts using the above criteria. However, the "Maintains Initial Settings", "Availability of Spare Parts" and "Durability of System" items are excluded because actual operator experience would be required for meaningful answers.

The third section encompasses Questions 4 through 11. Question 4 asks the operator which device he would prefer; his existing one, Concept 1, Concept 2 or another device, if purchase and installation costs were no obstacle. Question 5 queries the operator on his preferred choice, given purchase and installation costs. It indicates the "effective demand" for the new devices ie. the number of operators who prefer them, once they must recognize their own ability to finance them, the possible availability of cheaper and less effective alternatives and their sunken investment in existing devices. An operator indicating a preference for one of the new devices in Question 4, but preferring to remain with the existing system in Question 5, will have been deterred by the cost of the new systems. Thus a comparison of Questions 4 and 5 will indicate the degree to which price is a factor in affecting the demand for the systems.

A respondent indicating a desire for a specific new concept might nevertheless feel that the other design, while less suitable, is still superior to those now available on the market. If his/her preferred choice were not available, the operator might therefore be willing to accept the other concept. An operator who, in Question 5, indicated a preference for one of the two concepts, is asked in Question 6 if the other concept would be the second

choice. Since it is likely that only one of the two systems will be produced, this question eliminates one possible source of error. Suppose that the questionnaire yielded the following results:

	Preferred Device from Question 5 (Number of Respondents)
Concept 1	20
Concept 2	30

	Will Accept Other device as Second Best (Number of Respondents)
Those who selected Concept 1 in Question 5	5
Those who selected Concept 2 in Question 5	19

The total maximum potential demand for Concept 1 will be those who desire it as a first choice (20), plus those who, while actually prefer Concept 2, would accept Concept 1 as a compromise (19) ie. 39 persons. similarly, the maximum demand for Concept 2 is (30) + (5) or 35 operators. Consequently, while Concept 2 is the most popular <u>first</u> choice, Concept 1 has the larger market potential.

Questions 7 to 9 explore the impact of the preferred choice of device on efficiency, operating costs and ridership. If the new devices allow for more rapid securement of wheelchairs and restraint of passengers, and require less inspection or readjustment, vehicle boarding and deboarding times may be shortened dramatically. Operating costs may fall if the devices allow a vehicle and driver to generate more trips over a given time period. The improvemnt in customer service may stimulate the handicapped to make more discretionary trips on the vehicles or may allow a service overtaxed by passenger demands to increase volumes through better fleet utilization.

Question 10 queries whether the operator would make a rapid or gradual change to the new devices while question 11 queries as to the exact number of devices the operator may require.

The fourth part of the questionnaire, Questions 12 to 14, collect general data on each operation; the number of vehicles, weekly volumes, etc. and Question 15 requests operator comments. These are reproduced verbatim in Appendix D.

III. QUESTIONNAIRE RESPONSE RATES

Appendix 3 lists the operators to whom the questionnaires were sent. As of November 3, 1987 twenty-three (23) of the 45 companies had responded. All companies which had not yet responded were queried in mid-October. Table 1 presents the number of responses and the reasons cited by the operator for non-response. The "Unable to Reach" category included companies for which Directory Assistance had no record. It also included companies who were located and called but for which answers were not forthcoming. Reasons might include managers being repeatedly unavailable. If the third telephone call had failed either to reach the intended target, or to provide a clear lead, the company was placed in this category. Many respondents let contracts to third parties to operate the services. Some companies relayed the questionnaire to the contractor for input. Some responses were delayed as a result. The switch to a new contractor was responsible for two companies failing to respond. The postal strike, which occurred after the questionnaires had been mailed, no doubt harmed response rates and timeliness.

TABLE 1 - QUESTIONNAIRE RESPONSES

Total Number of Respondents	23
Company completed and returned questionnaire, but it has not been received	3
No knowledge of receiving questionnaire	6
Company under new management	2
New contractor operating service	2
Unable to locate company	9
Total number of non-responses	22
Total number of questionnaires mailed out	45

Generally, the questionnaire was well received. Several operators went to considerable effort to complete the form, often seeking the assistance of drivers, contractors or maintenance staff. Most responses showed considerable thought and care. For example, in assessing the impact of the concepts on vehicle capacities and utilization, several operators had inspected their

vehicles to determine placement of the new wheelchair securement/passenger restraint devices, and calculated hypothetical traffic loads rather than to provide an opinion based on rough intuition. Most companies which had not responded still expressed interest in the study, and welcomed the opportunity to discuss their operations.

The twenty-three responses correspond to a response rate of 51%, which is considered oustanding in an exercise of this nature.

IV. ANALYSIS OF QUESTIONNAITRE RESULTS - METHODOLOGY

The sample size is not sufficient to allow a statistical analysis based on a standard hypothesis testing procedure. The responses from most areas of Canada, many climatic zones, and operations varying vastly in fleet size and passenger volume, will lead to very small sizes of individual classes, with resulting problems for a parametric or non-parametric statistical analysis. Responses of an "Excellent", "Acceptable" or "Not Acceptable" form can be assigned numerical values, but subsequent analysis must be performed with caution. Since the data is not on an interval or ratio scale, an assumption of underlying normality cannot be made, and samples are generally too small for the Central Limit Thereom (in which the sample mean asymptotically approaches a normal distribution as the sample size increases) to become effective. This in turn precludes an Analysis of Variance, because the F-test assumes normality. A typical application of ANOVA techniques would be to evaluate an operator's satisfaction with his existing devices, or his response to the two proposals, as a function of the devices he is already using. The "treatment" variable would be the devices currently in use. However, the most popular device, the Q-Straint, was utilized by only six respondees, and the class size and normality problems preclude a rigourous parametric test.

Two methods are used to assess questionnaire results. Tabulation and visual inspection of results allows numerous inferences to be made about the operators' satisfaction with existing devices and their reactions toward the new concepts. "Combining the "Excellent" and "Acceptable" responses can simplify this process by isolating clearly identified areas of defficiency. The second method is based on assigning a numerical value of one to all "excellent" responses, a zero to "Acceptable" and a minus one to all "Unacceptable" answers. With 23 questionnaires returned the maximum score a device may attain is +23 (all respondents declare it "Excellent"); the minimum -23 (all respondents declare the system "Unacceptable"). Adding these indices over all questionnaires, and over all selection criteria, provides a single scale, a large value of which is indicative of market acceptance.

V. QUESTIONNAIRE RESPONSES

1. Existing Systems

Appendix 4 tabulates questionnaire results describing the operator's degree of satisfaction with existing systems. Tables 2-6 summarize these results further. Respondents employ a wide range of wheelchair securement/passenger restraint hardware, including Weco, Q-Straint, and various devices designed and manufactured in-house.

TABLE 2 - "EXCELLENT" RATINGS

	EXISTING	CONCEPT 1	CONCEPT 2
Comfort / dignity	65%	37%	26%
Ease of use	48%	5%	0%
Ease of maintenance	57%	17%	25%
Ease of installation	45%	11%	0%
Wheelchair accommodation	48%	26%	17%
Scooter accommodation	9%	28%	18%
Emergency release	33%	13%	8%
Maintains settings	61%	NA	NA
Availability of spares	41%	NA	NA
Durability	41%	NA	NA

TABLE 3 - "ACCEPTABLE" RATINGS

	EXISTING	CONCEPT 1	CONCEPT 2
Comfort / dignity	35%	53%	58%
Ease of use	39%	70%	53%
Ease of maintenance	39%	72%	63%
Ease of installation	50%	68%	72%
Wheelchair accommodation	39%	63%	56%
Scooter accommodation	41%	50%	65%
Emergency release	48%	81%	67%
Maintains settings	35%	NA	NA
Availability of spares	55%	NA	NA
Durability	59%	NA	NA

TABLE 4 - "UNACCEPTABLE" RATINGS

	EXISTING	CONCEPT 1	CONCEPT 2
Comfort / dignity	0%	11%	16%
Ease of use	13%	25%	47%
Ease of maintenance	4%	11%	13%
Ease of installation	5%	21%	28%
Wheelchair accommodation	13%	11%	28%
Scooter accommodation	50%	22%	18%
Emergency release	19%	6%	25%
Maintains settings	4%	NA	NA
Availability of spares	5%	NA	NA
Durability	0%	NA	NA

TABLE 5 - "EXCELLENT" AND "ACCEPTABLE" RATINGS

	EXISTING	CONCEPT 1	CONCEPT 2
Comfort / dignity	100%	89%	84%
Ease of use	87%	75%	53%
Ease of maintenance	96%	89%	88%
Ease of installation	95%	79%	72%
Wheelchair accommodation	87%	89%	72%
Scooter accommodation	50%	78%	82%
Emergency release	81%	94%	75%
Maintains settings	96%	NA	NA
Availability of spares	95%	NA	NA
Durability	100%	NA	NA

TABLE 6 - COMPOSITE SCORES

	EXISTING	CONCEPT 1	CONCEPT 2
Comfort / dignity	15	5	2
Ease of use	8	-4	-9
Ease of maintenance	12	1	2
Ease of installation	9	-2	-5
Wheelchair accommodation	8	3	-2
Scooter accommodation	-9	1	0
Emergency release	3	1	-2
TOTAL	46	5	14
Maintains settings	13	NA	NA
Availability of spares	8	NA	NA
Durability	9	NA	NA

A discussion of each performance criterion follows:

Passenger Comfort/Dignity

All respondents regarded their systems as either "Excellent" or "Acceptable". The composite score of 15 in this criterion is the highest scored on any criteria by either the existing system or the proposed concepts.

Ease of Use for Drivers/Attendants

Both the Excellent/Acceptable count of 87% and the composite score of 8 indicate a mediocre performance of existing systems in comparison to other criteria.

Ease of Maintenance

Fully 96% of respondents found their existing systems either "Excellent" or "Acceptable". The composite score of 12 indicates strong market satisfaction with the status quo.

Ease of Installation

The 95% Excellent/Acceptable score shows general market satisfaction. The composite score of 9 is lower than for other criteria, partly because of the large (50%) "Acceptable" rating, which is assigned a zero weight in the composite score.

Accommodation of Different Makes and Sizes of Wheelchairs

Existing systems generated a mediocre performance; an 87% Excellent/Acceptable proportion and a composite score of 8.

Accommodation of Scooters

This was a weak area, as predicted by the Porter study. Only 9% of operators considered existing systems "Excellent"; 41% found them only "Acceptable". A composite score of -9 is very poor; and is the only negative score generated by devices currently in use. This is by far the greatest defficiency in existing systems in the opinion of the respondents.

Emergency Release

The emergency release is a second problem area; 19% of respondents considered this safety feature "Unacceptable" in the devices they now employ. The composite score of 3 is the second lowest recorded by systems now in use.

Maintains Settings

A strong performance by existing systems. 96% of the respondenets indicated that existing systems were either "Excellent" or "Acceptable". The composite score of 13 indicates a high degree of satisfaction with existing systems.

Availability of Spare Parts

95% of respondents found existing systems either "Excellent" or "Acceptable". The mediocre composite score of 8 results from the large number of "Acceptable" ratings (55%).

Durability

All respondents considered existing systems either "Excellent" or "Acceptable". The composite score of 9 results from the large number of respondents claiming that the durability of their devices was "Acceptable". These responses received zero weight in the calculation of the index.

There were few clear relationships between the ratings provided by operators of their existing wheelchair restraint/passenger securement mechanisms. The Aeroquip FF865 received uniformly "Excellent" or "Acceptable" ratings. Operators were unhappy with the Q-Straint for conveying persons using scooters. Of six users, only one judged the Q-Straint "Acceptable"; all other provided "Unacceptable" grades.

2. Questionnaire Responses - Concept 1 vs. Existing Systems

Some respondents hesitated to rate the new concepts, claiming that "seeing is believing". While 21 completed questionnaires were returned, some respondents did not comment on certain criteria pertaining to the new concepts. These instances were ignored in the analysis of the questionnaire; the "Excellent", "Acceptable" and "Unacceptable" ratings of Appendix 5 are percentages of the number of operators answering these questions; not the total number of respondents. Non-responses were ignored in the calculation of composite scores.

In assessing Concepts 1 and 2, the criteria "Maintains Settings", "Accessibility of Spares" and "Durability" were excluded, since operators can only ascertain these factors from practical experience.

Concept 1 was rated as inferior to the existing systems in the following evaluation criteria:

- Passenger Comfort/Dignity
- Ease of Use for Drivers/Attendants
- Ease of Maintenance
- Ease of Installation

In each of the above instances, it gathered fewer "Excellent", fewer "Excellent" Plus "Acceptable" and more "Unacceptable" responses than existing concepts. Composite scores were also significantly lower.

Accommodation of Different Makes and Sizes of Wheelchairs

Concept 1 again underperperformed existing concepts. Fewer operators classified it as superior to existing wheelchair securement/passenger restraint devices and the composite score was less. However, 89% of respondents considered concept 1 either "Excellent" or "Acceptable" while existing devices scored 87%. 11% found Concept 1 "Unacceptable" compared to 13% for existing systems.

Accommodation of Scooters

Concept 1 significantly outperformed existing devices in this important criterion. 78% of respondees felt it was either "Excellent" or "Acceptable", compared to 50% for existing systems. While fully 50% of respondents found their devices "Unacceptable", only 22% so graded Concept 1. The composite score for Concept 1 , while a relatively low 1, still clearly exceeded the -9 earned by existing systems.

Emergency Release

While 94% of respondents regarded the Concept 1 emergency release mechanism as either "Excellent" or "Acceptable" only 81% gave similar grades to the devices in use. Concept 1 was considered "Excellent" by 13% of respondents; compared to 33% for existing devices. The composite score of existing systems marginally exceeded that of Concept 1. Concept 1 can be considered as slightly superior to existing systems because of the large number of respondents (81%) considering it "Acceptable".

3. Questionnaire Responses - Concept 2 versus Existing Systems

Questionnaire respondents considered Concept 2 to be inferior to existing devices in the following criteria:

- Passenger Comfort/Dignity
- Ease of Use for Drivers/Attendants
- Ease of Maintenance
- Ease of Installation
- Accommodation of Different Makes and Sizes of Wheelchairs
- Emergency Release

In every criteria, Concept 2 obtained fewer "Excellent" ratings, fewer "Excellent" + "Acceptable" ratings, more "Unacceptable" ratings, and a lower composite score.

In the "Accommodation of Scooters" criterion, Concept 2 was judged by the respondents to be clearly superior to existing devices, as indicated by a higher proportion of respondents declaring it "Excellent", a higher "Excellent" + "Acceptable" score, a lower "Unacceptable" score and higher composite score.

4. Concept 1 versus Concept 2

Concept 1 outperformed Concept 2 in the following areas:

- Passenger Comfort/Dignity
- Ease of Use for Drivers/Attendants
- Ease of Installation
- Accommodation of Different Makes and Sizes of Wheelchairs
- Emergency Release

In these criteria, Concept 1 was rated as "Excellent" by more respondents than Concept 2, and more respondents considered it either "Excellent" or "Acceptable". Concept 1 was considered "Unacceptable" by fewer persons than Concept 2 and its composite scores in these criteria were higher.

Ease of Maintenance

Questionnaire results were ambiguous. 25% of the respondents considered Concept 2 to be "Excellent" in this criterion, compared to 17% for Concept 1. However, 13% of the respondents felt that Concept 2 was "Unacceptable" compared to 11% for Concept 1. Concept 2 attained a marginally higher composite score.

Accommodation of Scooters

The questionnaire failed to reveal the market preferences between Concept 1 and Concept 2. Concept 1 had more outlying (ie. "Excellent" and "Unacceptable" responses) than Concept 2, which received a large number of "Acceptable" ratings. Overall, 82% of the respondents consider Concept 2 to be either "Excellent" or "Acceptable", compared to 78% for Concept 1. The composite score of Concept 1 was 1; that for Concept 2 was 0, indicating that "Excellent" and "Unacceptable" ratings were closely offsetting.

5. Market Demand

Questions 4 and 5 determine the operators willingness to purchase the new concepts. Question 4 examines the preferred choice if "purchase and installation cost were no obstacle" while Question 5 asks operators on their choice given the cost of each concept as presented in the concept drawings and descriptions mailed to each operator as part of the questionnaire. A comparison of Questions 4 and 5 will indicate the extent to which an operator's choice is sensitive to unit costs.

Table 7 summarizes operator preferences for those companies expressing an interest in the new concepts in Question 5.

TABLE 7

	Prefer Concept 1	Prefer Concept 2
# Vehicles	18	5
# Passengers per Week	2532	305
%Passengers using Wheelchairs	41.8	59.4
Total # Systems	59	5
Total Saleable Demand	62	64

One operator did not state the number of systems required; an estimation was made based on three devices per vehicle.

Four of the twenty-three operators would prefer Concept 1 if purchase price were no obstacle, and two operators would prefer Concept 2. Once purchase and installation costs are factored into the operator choice in Question 5, three operators still prefer Concept 1 and two prefer Concept 2. In other words, one operator was deterred by the costs of the device from replacing his existing system with Concept 1. The price of the devices is an obstacle of only limited importance to their acceptance by the market.

Four operators interested in the new concepts have indicated that, if their preferred choice were not available, they would be willing to accept the alternate concept. One operator who voiced a desire for Concept 2 would not purchase Concept 1 in lieu of the preferred choice for the two devices needed. It is for this reason that the "total saleable demand" for Concept 2 is slightly higher than for Concept 1.

Companies purchasing the devices prefer to phase them into their vehicle fleets gradually, often over a period of several months.

Operators choosing the new concepts tend to be very small. The average size is 4.6 vehicles, and 571 passengers per week. This compares to an average over all operators in the sample of 17 vehicles and 1660 persons/week per operator. There is obvious explanation for this trend, although smaller operators may either have a smaller investment in existing equipment or may be financed in a different manner than the larger companies in the sample.

The companies who responded with an interest in the new concepts would collectively require approximately sixty-four devices (one small operator did not state his requirements). These operators collectively account for 5.6% of the total person-trips of all respondents.

There was no relationship between the devices used by the operators and their willingness the purchase the new devices. Persons interested in the new concepts used a wide and representative range of restraint/securement devices.

The telephone survey of companies who failed to respond to the questionnaire confirmed that operators are generally unreceptive to the new devices. One stated that new systems were too expensive, and that he was well satisfied with his existing wheelchair securement / passenger restraint devices. A second operator believed that the concepts were too bulky to be employed in its small vans. Others did not view the securement/restraint systems as an issue of major operational importance.

6. Impact of the Prposed Systems on Operations

Two operators expected that the concepts positively affect the efficiency of the vehicle boarding/de-boarding process, three anticipate no change. Four operators expect operating costs to be unaffected while one expects a higher level of operating costs. None of the operators expressing an interest in the new concepts expect any impact on ridership.

VI. SUMMARY

The major findings of the questionnaire survey can be summarized as follows:

- Existing devices are considered satisfactory in most regards, but are viewed as being defficient in the areas of accommodation of scooters and emergency release mechanisms.
- Operators tend to be unreceptive to the new concepts, and tend to prefer their existing systems.
- Concept 1 is generally viewed as being superior to Concept 2 by the operators.
- Purchase price and installation costs do not play a paramount role in an operator's decision to adopt the new devices.
- The new devices are not expected to have a major impact on the operation of handicapped transportation systems as a result of more efficient operations, greater numbers of passengers carried, etc.

VII. RECOMMENDATIONS

It is recommended that Concept 1 be selected, and that a comprehensive field demonstration and testing procedure be initiated immediately. Concept 1 has a superior market acceptance and major perceived advantages over Concept 2.

Although the questionnaire results do not encourage a field test program, the high response rate and meticulous comments provided by many operators suggest a strong interest in the whole question of wheelchair securement and passenger restraint. The market cannot be considered indifferent; and there should be a strong receptivity to devices having clear benefits to the operators and their patrons.

Discussions with the operators indicated their strong operational and pragmatic focus. They relate more closely to day-to-day issues and tangible measures of performance rather than abstractions. Asking the operators to compare descriptions and drawings of hypothetical concepts to systems currently owned and in use is placing the former at a severe disadvantage. A respondent is unlikely to classify any aspect of a device presented in this manner as "excellent", and is likely to over-respond to any perceived faults. The questionnaire is therefore very conservative, and is, if any form of error is made, more likely to lead towards the undue rejection of the new concepts and the mistaken retention of the status-quo, rather than an

unwarranted decision to reject existing systems. A more accurate terst-marketing process would include presenting potential purchasers with actual prototypes and mockups, with viewpoints collected by a direct interview.
Operators clearly liked the ability of either concept to accommodate scooters. Both were viewed as superior to systems now in use in this regard.

Those operators interested in purchasing the concepts would prefer a gradual phase-in of these devices. It would appear that they have no strong aversion to running a mixed fleet, but would value the opportunity to test the new devices alongside the old. Even those among the majority of operators who have chosen to remain with existing devices might welcome the opportunity to participate in the test program.

Concept 1 rather than Concept 2 should be the focus of the testing program because of the more favourable reaction to it in the questionnaire. It is also less expensive than Concept 2.

If Concept 1 is to offer operators a significant opportunity + to improve transportation services to the disabled, it must overcome certain perceived shortcomings. It is viewed as being significantly defficient to existing devices in the areas of comfort/personal dignity, ease of use and ease of maintenance. It is also viewed as being somewhat more difficult to install on the vehicle. Its major strength over existing devices is in its perceived superiority in anchoring scooters.

APPENDIX 1

THE QUESTIONNAIRE
(English)

WHEELCHAIR SECUREMENT

AND

PASSENGER RESTRAINT

QUESTIONNAIRE

SYPHER:MUELLER International Inc.

August 26, 1987

D22

SYPHER: MUELLER

WHEELCHAIR SECUREMENT AND PASSENGER RESTRAINT QUESTIONNAIRE

1. Who is the manufacturer, and what is the model number/name of the wheelchair securement system you are using now? (If you are now using more than one type of system, please quote the one you consider, overall, the most satisfactory in Questions 1 and 2.)

   Manufacturer _____
   Model Number _____

   Is your existing system comprised of:

   A shoulder and lap belt?

   YES ____ NO ____

   A lap belt only?

   YES ____ NO ____

2. Please rate your existing wheelchair securement and passenger restraint system by:

	Excellent	Acceptable	Unacceptable
Maintains initial settings - no need to check, tighten, or re-adjust fittings during transportation. CHECK ONE:	____	____	____
Comfort/personal dignity of passengers CHECK ONE:	____	____	____
Ease of use for drivers and attendants eg. amount of time needed to secure wheelchairs and restrain passengers CHECK ONE:	____	____	____

SYPHER: MUELLER

	Excellent	Acceptable	Unacceptable
Ease of maintenance.			
CHECK ONE:	___	___	___
Availability of spare parts.			
CHECK ONE:	___	___	___
Ease of installing system on vehicle			
CHECK ONE:	___	___	___
Ability to accommodate different makes and sizes of wheelchairs			
CHECK ONE:	___	___	___
Ability to accommodate scooters			
CHECK ONE:	___	___	___
Emergency release			
CHECK ONE:	___	___	___
Durability of system			
CHECK ONE:	___	___	___

3. ENCLOSED ARE SPECIFICATIONS AND DESCRIPTIONS FOR TWO PROPOSED WHEELCHAIR SECUREMENT/PASSENGER RESTRAINT SYSTEMS WHICH MEET APPLICABLE SAFETY STANDARDS. PLEASE INDICATE YOUR REACTION TO THESE PROPOSED SYSTEMS BY ANSWERING THE FOLLOWING QUESTIONS:

CONCEPT 1	Excellent	Acceptable	Unacceptable
Ease of Installing system on vehicles			
CHECK ONE:	___	___	___

SYPHER: MUELLER

	Excellent	Acceptable	Unacceptable
Ease of use for drivers or attendants			
CHECK ONE:	___	___	___
Comfort/personal dignity of passengers			
CHECK ONE:	___	___	___
Ease of maintenance			
CHECK ONE:	___	___	___
Emergency release			
CHECK ONE:	___	___	___
Ability to accommodate different makes and sizes of wheelchairs			
CHECK ONE:	___	___	___
Ability to accommodate scooters			
CHECK ONE:	___	___	___

CONCEPT 2	Excellent	Acceptable	Unacceptable
Ease of Installing system on vehicles			
CHECK ONE:	___	___	___
Ease of use for drivers or attendants			
CHECK ONE:	___	___	___
Comfort/personal dignity of passengers			
CHECK ONE:	___	___	___

SYPHER: MUELLER

	Excellent	Acceptable	Unacceptable
Ease of maintenance			
CHECK ONE:	___	___	___
Emergency release			
CHECK ONE:	___	___	___
Ability to accommodate different makes and sizes of wheelchairs			
CHECK ONE:	___	___	___
Ability to accommodate scooters			
CHECK ONE:	___	___	___

4. Which securement/restraint system would you prefer to use, if purchase and installation cost were no obstacle:

   - o Your existing system
   - o Concept 1
   - o Concept 2
   - o Other (please specify) _____

5. Which system would you prefer to use, given estimated purchase and installation costs?

   - o Your existing system
   - o Concept 1
   - o Concept 2
   - o Other (please specify) _____.

IF YOU HAVE SELECTED CONCEPT 1 OR CONCEPT 2 IN QUESTION 5, PLEASE ANSWER THE FOLLOWING QUESTIONS. OTHERWISE, PLEASE SKIP DOWN TO QUESTION 12.

6. If the preferred concept you checked in Question 5 was not available, would you consider the other concept to be acceptable?

   YES ____ NO ____

7. How would the concept indicated in Question 5 affect the efficiency of your operation considering vehicle boarding/deboarding times?

   - o More effective
   - o No change
   - o Less effective

8. Your use of the concept indicated in Question 5 might permit several changes to your operation (eg. installation, maintenance, passenger boarding, passenger capacity). How do you believe the concept will affect your operating costs?

   - o Costs will decrease
   - o No change
   - o Costs will increase

9. How do you believe your use of the concept indicated in Question 5 will affect ridership:

   - o Increase
   - o No change
   - o Decrease

10. If your preferred concept indicated in Question 5 was available would you replace existing securement/restraint systems immediately or gradually phase in the new equipment?

    - o Immediate replacement of old systems with proposed concept.
    - o Gradual phase-in over several months
      Months required for phase-in: _____

11. How many of the proposed systems would you require?

    _____

SYPHER: MUELLER

12. How many vehicles which can accommodate wheelchairs do you presently operate?

_____

13. Approximately how many disabled persons do you transport in an average week? (One person on a return trip counts as two).

_____

14. What percentage of your passengers are wheelchair users?
_____%

15. Any comments or suggestions would be appreciated.

16. We may wish to contact you by telephone to discuss your responses to this questionnaire.

Name of your organization:

Your name:

Telephone number: Area Code ( )

T H A N K Y O U

SYPHER: MUELLER

CONCEPT 1

Description

- A system of retractable belts and hooks secures the wheelchair at four points (Figure 1).
- Passenger restraint is provided by a retractable lap belt and torso belt. The belts connect at the outboard latch to allow the lap belt to be routed under the wheelchair armrest for better fitment while retaining single latch-action release of the system.
- The passenger sits facing the direction of travel.
- The securement system may be used in any bus or van model and adapts to most wheelchair types (Figure 2).
- All restraint belts are stored inside the floor mounted structure.
- If several wheelchairs are to be secured in a line, only one floor mounted structure need be installed between each wheelchair as the front support structure for one wheelchair serves as the rear support structure of the wheelchair directly in front.

Operation

- The driver/assistant manoeuvers the wheelchair adjacent to the restraint area and in the direction of travel.
- The rear harness (Item 1) and retractable front belts (Items 2) are attached to the wheelchair.
- The wheelchair is manoeuvered into the designated area.
- The front belts will automatically retract as the wheelchair is moved into position and are then locked in place with the lever (Item 3).
- The retractable rear belt (Item 4) is spooled out, attached to the rear harness and then tensionned using a ratchet lever (Item 5).
- The aisle side lap buckle is placed in the designated position. The retractable lap belt (Item 6) is passed below the wheelchair armrests and fastened into the buckle.
- The retractable torso belt (Item 7) is positioned across the passengers upper body, beneath the outside armrest and fastened onto the lap belt.

Capital Cost

The retail cost of this wheelchair securement and occupant restraint system is estimated between $500 and $800.

Installation and Maintenance Requirements

Local reinforcement is required surrounding the upper torso belt anchorage and the main floor plate.

Monthly cleaning and inspection of all components is recommended, however, bi-annual maintenance checks should be more than adequate.

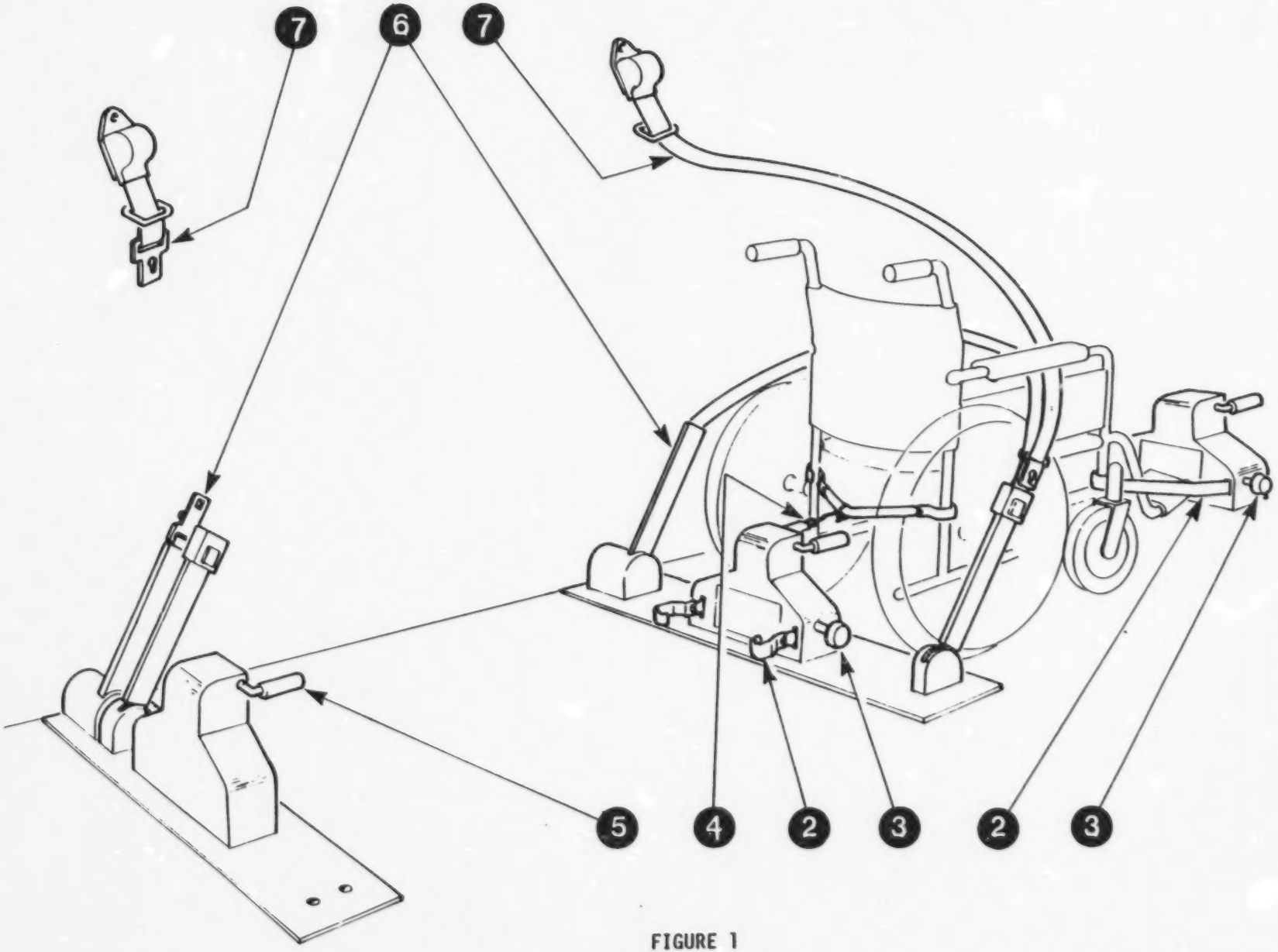

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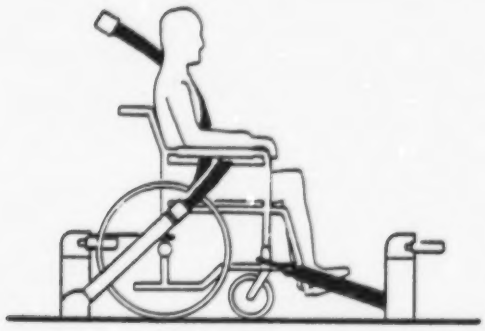
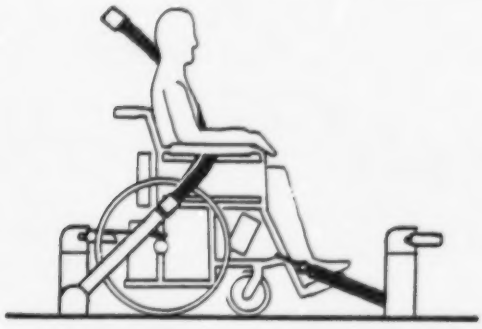
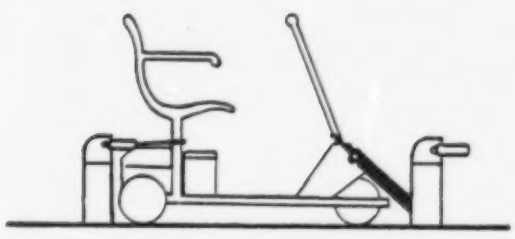
FIGURE 1
CONCEPT 1



Standard Manual

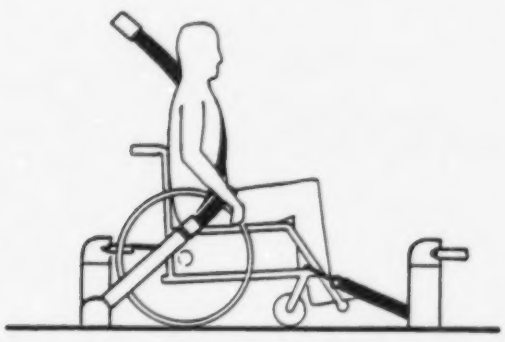


Standard Electric



Scooter

Note: Passenger is transferred to an adjacent ambulatory seat and the scooter is secured.



Sport Chair

FIGURE 2

WHEELCHAIRS ACCOMMODATED - CONCEPT 1

CONCEPT 2

Description of Concept 2

- This concept utilizes two independent systems to secure the front and rear of a wheelchair.
- The rear securement system consists of two adjustable telescopic bars connected to a floor mounted structure (Figure 1).
- The front securement system consists of a padded cross bar which is placed horizontally over the front of the lower wheelchair frame and held in place on the vehicle wall and the aisle side vehicle floor.
- Passenger restraint is provided by a retractable lap belt and torso belt.
- The passenger sits facing the direction of travel.
- The securement system may be used in any bus or van model and adapts to most wheelchair types (Figure 2).

Operation of Concept 2

- The driver/assistant manoeuvers the wheelchair into the designated area with the chair facing in the direction of travel.
- The front securement bar (Item 1) is positioned horizontally securing the lower front frame of the wheelchair, using the wall anchor tracks and the aisle side floor anchor channel.
- The wall tracks allow horizontal and vertical adjustment of the front securement bar to ensure fitment and adequate down-force to various wheelchair frames.
- For narrower vehicles, the securement bar can be supplied as a telescopic unit to reduce the lateral space required for deployment.
- The rear telescopic bars (Item 2) are attached to the rear vertical posts of the wheelchair immediately above or below the armrests and locked into place.
- The arms are free to pivot and swivel with length adjustment handled by a simple pin/hole mechanism.
- The aisle side lap buckle is placed in the designated position. The retractable lap belt (Item 3) is passed below the wheelchair armrests

and fastened into the buckle.

- The retractable torso belt (Item 4) is positioned across the passengers upper body, beneath the outside armrest and fastened onto the lap belt.

Capital Cost

The retail cost of this wheelchair securement and occupant restraint system is estimated between $700 and $1,000.

Installation and Maintenance Requirements

Local reinforcement is required in the areas surrounding the floor mounted plate and the upper torso belt anchorage. Typical vehicle structures should provide sufficient integrity for mounting of the floor channel and wall track for the front securement system.

Monthly cleaning and inspection of all components is recommended, however, bi-annual maintenance checks should be more than adequate.

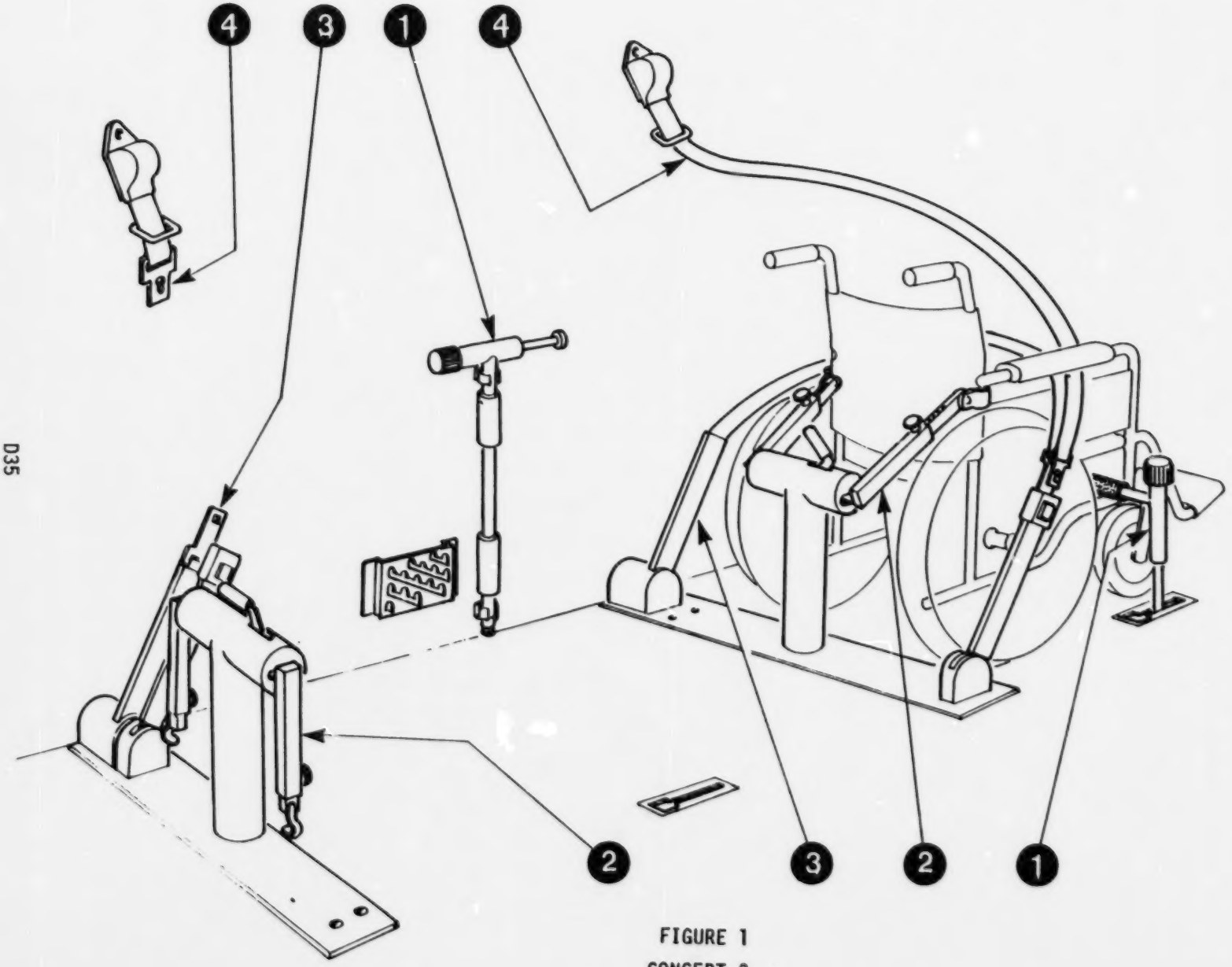


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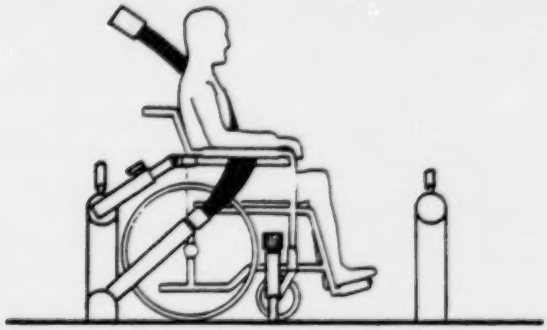
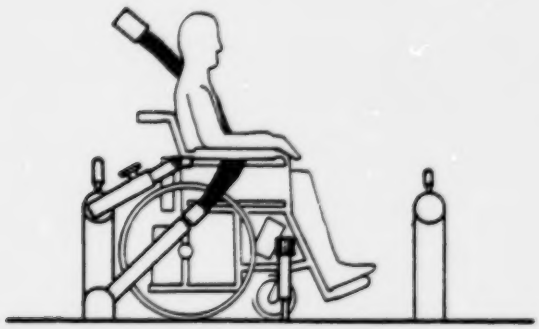
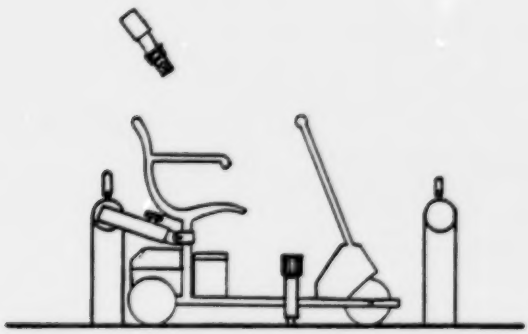
FIGURE 1
CONCEPT 2



Standard Manual

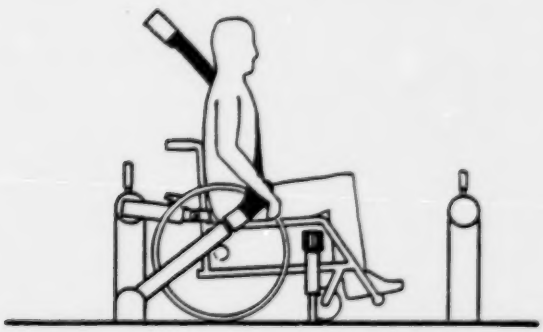


Standard Electric



Scooter

Note: Passenger is transferred to an adjacent ambulatory seat and the scooter is secured.



Sport Chair

FIGURE 2

WHEELCHAIRS ACCOMMODATED - CONCEPT 2

APPENDIX 2

THE QUESTIONNAIRE
(Francais)

QUESTIONNAIRE
SUR L'ANCRAGE DES FAUTEUILS ROULANTS
ET L'IMMOBILISATION DES OCCUPANTS

SYPHER : MUELLER International Inc.

26 août 1987

SYPHER : MUELLER

QUESTIONNAIRE

SUR L'ANCRAGE DES FAUTEUILS ROULANTS

ET L'IMMOBILISATION DES OCCUPANTS

1. Nom du fabricant du système d'ancrage de fauteuils roulants actuellement utilisé et modèle du système. Si plus d'une marque est utilisée, indiquez celle qui, à votre avis, donne le plus de satisfaction par rapport aux questions 1 et 2 :

   Fabricant _____

   Modèle _____

   Comprend-il
   Une ceinture abdominale et une diagonale?

   ☐ OUI ☐ NON

   Ou une ceinture abdominale seulement?

   ☐ OUI ☐ NON

2. Cotez le système d'ancrage et d'immobilisation actuellement utilisé :

	Excellent	Acceptable	Inacceptable
Ne se desserre pas - Nul besoin de réglage ultérieur Cochez une des cases	☐	☐	☐
Confort/dignité des passagers Cochez une des cases	☐	☐	☐
Facilité d'emploi : temps pris pour accomplir la manoeuvre Cochez une des cases	☐	☐	☐

SYPHER : MUELLER

	Excellent	Acceptable	Inacceptable
Facilité d'entretien			
Cochez une des cases	☐	☐	☐
Disponibilité des pièces de rechange			
Cochez une des cases	☐	☐	☐
Facilité de mise en place du système			
Cochez une des cases	☐	☐	☐
Adaptabilité aux différentes marques et dimensions de fauteuils roulants			
Cochez une des cases	☐	☐	☐
Aptitude à s'ajuster aux fauteuils type scooter			
Cochez une des cases	☐	☐	☐
Rapidité de déverrouillage			
Cocher une des cases	☐	☐	☐
Durée de vie			
Cochez une des cases	☐	☐	☐

3. Vous trouverez ci-jointes la fiche technique et la description de deux systèmes d'ancrage et d'immobilisation répondant aux normes de sécurité. Indiquez votre appréciation les concernant en répondant aux questions suivantes :

CONCEPT 1	Excellent	Acceptable	Inacceptable
Facilité de mise en place du système			
Cochez une des cases	☐	☐	☐

SYPHER : MUELLER

	Excellent	Acceptable	Inacceptable
Facilité d'emploi par le préposé ou l'accompagnateur			
Cochez une des cases	☐	☐	☐
Confort/dignité du passager			
Cochez une des cases	☐	☐	☐
Facilité d'entretien			
Cochez une des cases	☐	☐	☐
Rapidité de déverrouillage			
Cochez une des cases	☐	☐	☐
Adaptabilité aux différentes marques et dimensions de fauteuils roulants			
Cochez une des cases	☐	☐	☐
Aptitude à s'ajuster aux fauteuils type scooter			
Cochez une des cases	☐	☐	☐

CONCEPT 2	Excellent	Acceptable	Inacceptable
Facilité de mise en place du système			
Cochez une des cases	☐	☐	☐
Facilité d'emploi par le préposé ou l'accompagnateur			
Cochez une des cases	☐	☐	☐
Confort/dignité du passager			
Cochez une des cases	☐	☐	☐

SYPHER : MUELLER

	Excellent	Acceptable	Inacceptable
Facilité d'entretien			
Cochez une des cases	☐	☐	☐
Rapidité de déverrouillage			
Cochez une des cases	☐	☐	☐
Adaptabilité aux différentes marques et dimensions de fauteuils roulants			
Cochez une des cases	☐	☐	☐
Aptitude à s'ajuster aux fauteuils type scooter			
Cochez une des cases	☐	☐	☐

4. Quel système aurait votre préférence, sans égard aux coûts d'achat et d'installation :

   - ○ Votre système actuel
   - ○ Le concept 1
   - ○ Le concept 2
   - ○ Autre (précisez lequel) _____

5. Quel système aurait votre préférence, considérant les coûts estimatifs d'achat et d'installation mentionnés?

   - ○ Votre système actuel
   - ○ Le concept 1
   - ○ Le concept 2
   - ○ Autre (précisez lequel) _____

SI, À LA QUESTION 5, VOUS AVEZ INDIQUÉ UNE PRÉFÉRENCE POUR LE CONCEPT 1 OU POUR LE CONCEPT 2, VEUILLEZ RÉPONDRE AUX QUESTIONS SUIVANTES. AUTREMENT, VEUILLEZ PASSER DIRECTEMENT À LA QUESTION 12.

SYPHER: MUELLER

6. Si le concept que vous avez choisi à la question 5 n'existait pas sur le marché, accepteriez-vous d'opter pour l'autre?

☐ OUI ☐ NON

7. Eu égard aux temps de montée et de descente nécessaires, pensez-vous que le concept que vous avez choisi à la question 5 aurait pour effet :

- O - D'accroître l'efficacité de l'exploitation
- O - De diminuer l'efficacité de l'exploitation
- O - Aucun changement

8. À supposer que le concept que vous avez choisi à la question 5 ait des conséquences sur l'exploitation (ex. : installation, entretien, temps d'embarquement, capacité d'emport), pensez-vous qu'il aura pour effet :

- O - De réduire les coûts d'exploitation
- O - D'augmenter les coûts d'exploitation
- O - Aucun changement

9. Pensez-vous que la mise en oeuvre du concept que vous avez choisi à la question 5 aura pour effet :

- O - D'accroître la fréquentation
- O - De réduire la fréquentation
- O - Aucun changement

10. Si le concept que vous avez choisi à la question 5 existait sur le marché, envisageriez-vous de remplacer votre système actuel immédiatement ou bien progressivement?

- O - Remplacement immédiat
- O - Remplacement progressif
  Étalement sur...mois

11. De combien d'exemplaires du système choisi pensez-vous avoir besoin?

_____

SYPHER : MUELLER

12. À combien s'élève le nombre de véhicules adaptés que vous exploitez actuellement?

_____

13. À peu près combien de passagers handicapés sont transportés par votre entreprise par semaine? Un aller-retour compte pour deux.

_____

14. Quel est le pourcentage des passagers en fauteuil roulant?

_____

15. Avez-vous des commentaires ou des suggestions? Veuillez les donner ci-dessous.

16. Au cas où il serait utile que nous communiquions avec vous à ce sujet, veuillez donner les renseignements suivants :

Nom de l'entreprise : _____

Nom du répondant : _____

Numéro de téléphone : _____ Indicatif régional : ___

MERCI

SYPHER: MUELLER

CONCEPT 1

Description

- L'ancrage quatre points du fauteuil roulant fait appel à un ensemble de ceintures rétractables (figure 1).
- L'immobilisation du passager se fait par deux ceintures rétractables, l'une abdominale et l'autre diagonale, qui se fixent l'une à l'autre côté allée. L'abdominale passe sous les deux appuis-bras, ce qui lui permet de bien s'ajuster au corps du passager. Le système ne nécessite qu'une seule boucle.
- Le passager est assis dans le sens du mouvement.
- Le système d'ancrage s'adapte à tous les modèles de bus ou de fourgonnettes ainsi qu'à la plupart des fauteuils roulants (figure 2).
- Les ceintures (sauf la diagonale) s'enroulent dans un dispositif fixé au plancher.
- Dans le cas où plusieurs fauteuils sont placés l'un derrière l'autre, il suffit d'un seul dispositif d'ancrage au plancher entre deux fauteuils puisqu'il sert pour les deux en même temps.

Mode opératoire

- Le fauteuil est poussé à proximité du lieu qu'il doit occuper, dans le sens du mouvement.
- Le harnais arrière (1) est mis en place et les ceintures rétractables avant (2) sont accrochées au fauteuil.
- Le fauteuil est alors poussé dans la place qu'il doit occuper.
- Les ceintures avant s'enroulent automatiquement à mesure que le fauteuil est avancé, et elles sont verrouillées en place par la tige (3).
- La ceinture arrière (4) est déroulée, accrochée au harnais arrière et tendue à l'aide du cliquet (5).
- Le bras d'immobilisation est alors déplacé pour occuper la place qui lui est réservée côté allée. La ceinture abdominale (6) est déroulée, passée sous les deux appuis-bras et insérée dans la boucle.
- La ceinture diagonale (7) est déroulée, passée sous l'appui-bras du côté opposé et fixée à la ceinture abdominale.

Coût

Le système d'ancrage et d'immobilisation coûte au détail entre 500 et 800 $.

Installation et entretien

Les pièces d'ancrage dans la paroi du véhicule ainsi qu'au plancher nécessitent un renforcement local.

le nettoyage et l'inspection de tous les éléments devraient avoir lieu tous les mois, complétés par un contrôle plus poussé tous les six mois.

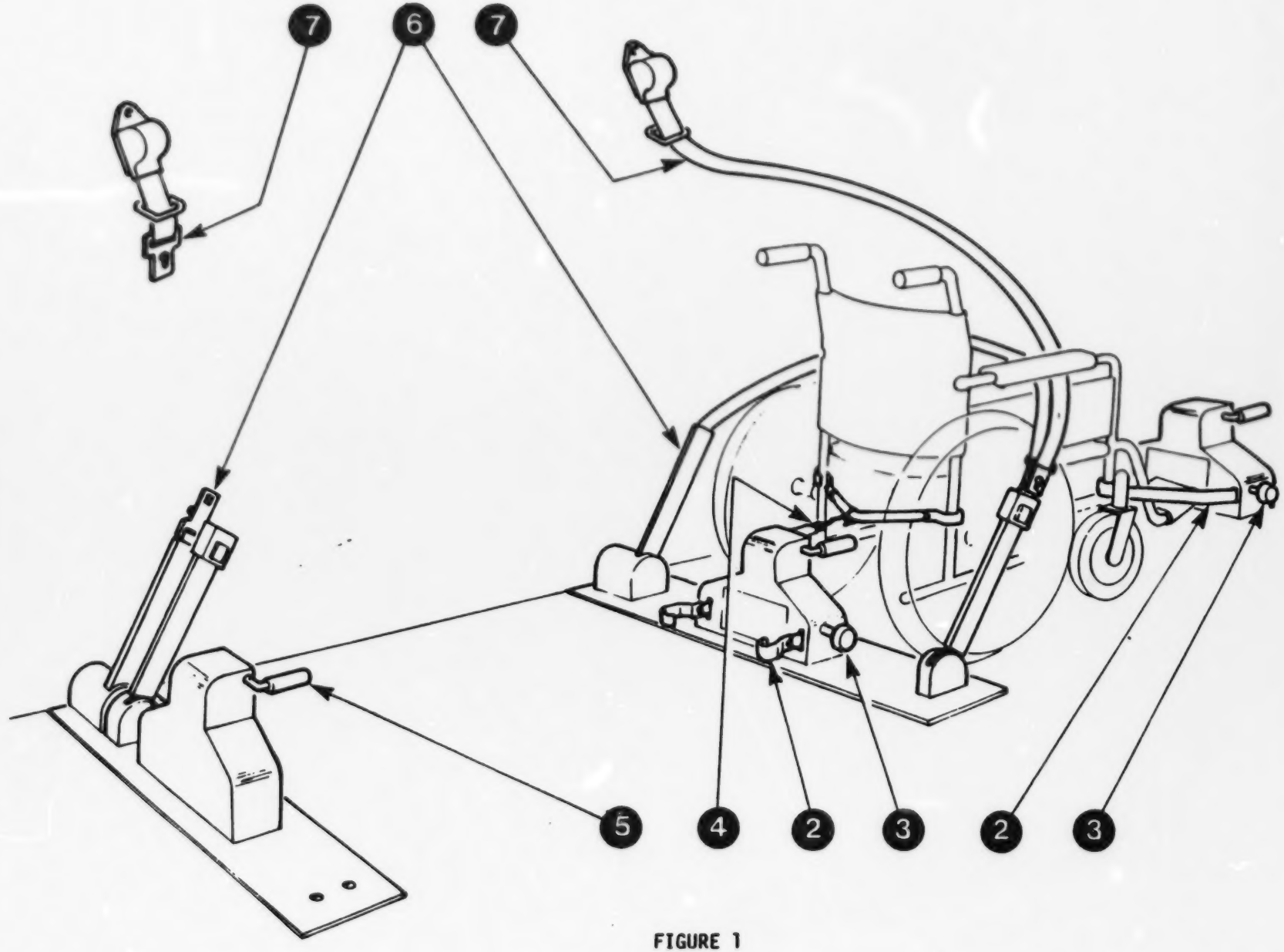
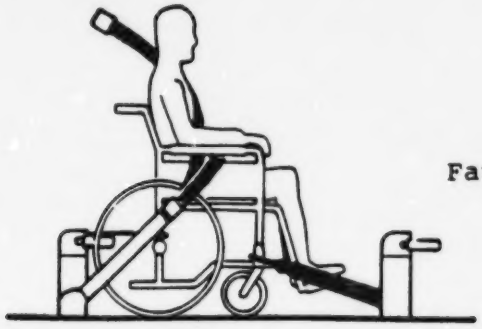
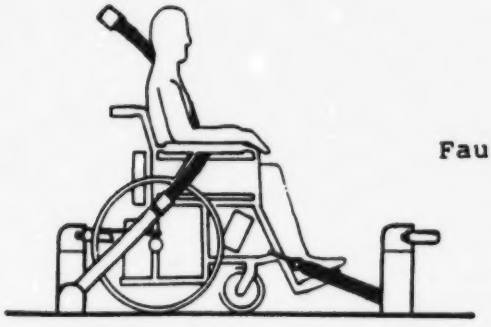


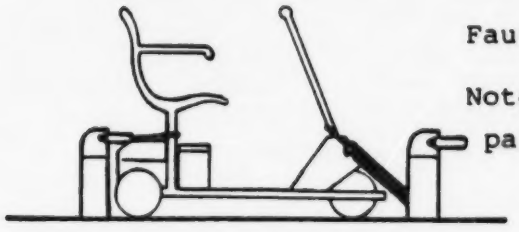
FIGURE 1
CONCEPT 1



Fauteuil manuel standard

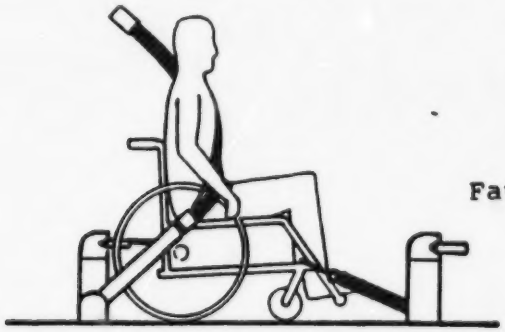


Fauteuil électrique standard



Fauteuil type scooter

Note: Le passager ne reste pas dans son "scooter", mais fait le trajet dans un siège, à proximité



Fauteuil type sport

FIGURE 2

Types de fauteuils acceptés - Concept 1

CONCEPT 2

Description

- Ce concept fait appel à deux sous-systèmes d'ancrage distincts, l'un à l'avant et l'autre à l'arrière.
- L'ancrage arrière comporte deux bras télescopiques, réglables en longueur, partant d'une structure fixée au plancher (figure 1).
- L'ancrage avant est un élément en T, à corps rembourré, qui bloque le fauteuil en s'appuyant sur les longerons inférieur de son bâti avant. Il se fixe, d'une part, dans la paroi du véhicule et, d'autre part, dans une fente pratiquée dans le plancher.
- L'immobilisation du passager se fait par deux ceintures rétractables, l'une abdominale et l'autre diagonale.
- Le passager est assis dans le sens du mouvement.
- Le système d'ancrage s'adapte à tous les modèles de bus ou de fourgonnette ainsi qu'à la plupart des fauteuils roulants (figure 2).

Mode opératoire

- Le fauteuil est poussé jusqu'à la position qu'il doit occuper, dans le sens du mouvement.
- L'élément en T (1) est placé de manière à bloquer le fauteuil en s'appuyant sur les longerons inférieurs de son bâti avant. Il est encastré, d'une part, dans l'une des fentes crantées d'une plaque fixée à la paroi du véhicule et, d'autre part, dans la fente du plancher.
- Les fentes crantées autorisent un réglage précis de l'élément en T dans le sens vertical et horizontal pour assurer une meilleure prise et une force de retenue suffisante.
- Cet élément en T peut être réalisé en version téléscopique afin de s'adapter à des fauteuils de largeur variée.
- Les bras télescopiques (2) de l'ancrage arrière s'agrippent aux montants arrière du fauteuil, soit au-dessus, soit au-dessous des appuis-bras.
- Ces bras sont articulés et leur longueur est réglable grâce à un système de crans et goupille.
- Le bras d'immobilisation est déplacé pour occuper la place qui lui est réservée côté allée. La ceinture abdominale (3) est déroulée, passée sous les deux appuis-bras et insérée dans la boucle.
- La ceinture diagonale (4) est déroulée, passée sous l'appui-bras du côté opposé et fixée à la ceinture abdominale.

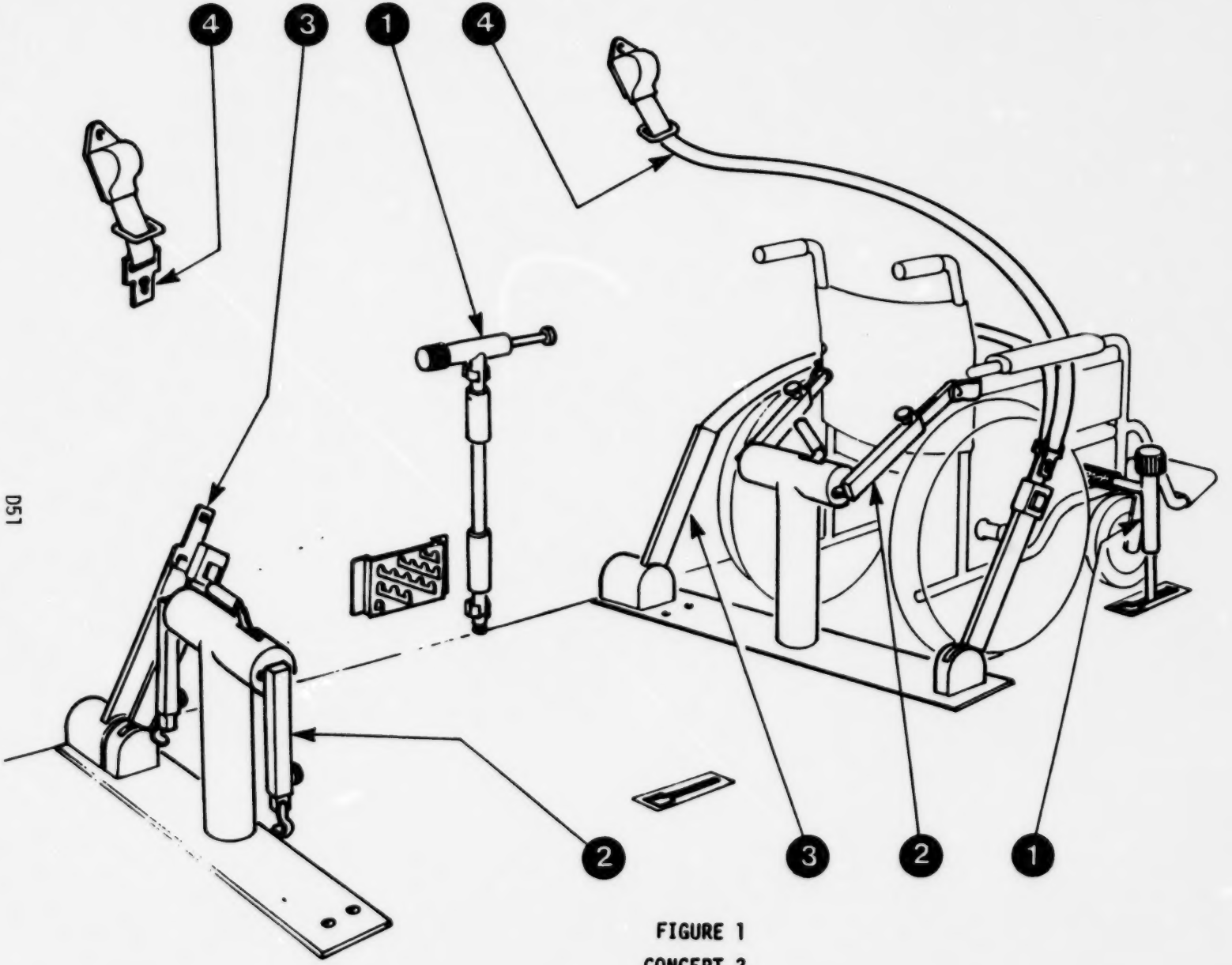
Coût

Le système d'ancrage et d'immobilisation coûte au détail entre 700 et 1,000 $.

Installation et entretien

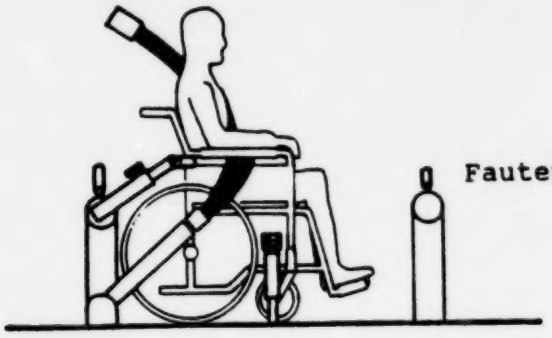
Les pièces d'ancrage dans la paroi et au plancher nécessitent un renforcement local. La structure des véhicules à équiper offre généralement la solidité voulue pour permettre la mise en place des plaques à fentes crantées ainsi que la réalisation de la fente au plancher.

Le nettoyage et l'inspection de tous les éléments devraient avoir lieu tous les mois, complétés par un contrôle plus poussé tous les six mois.

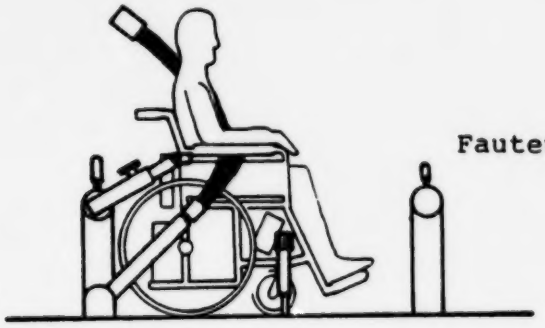


D51

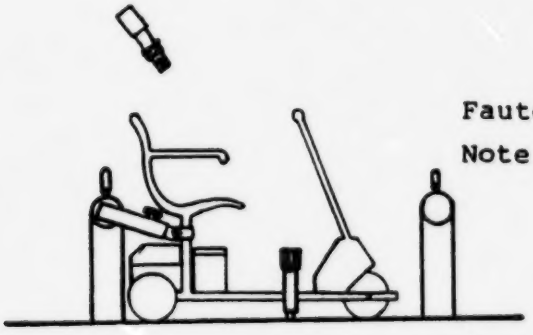
FIGURE 1
CONCEPT 2



Fauteuil manuel standard

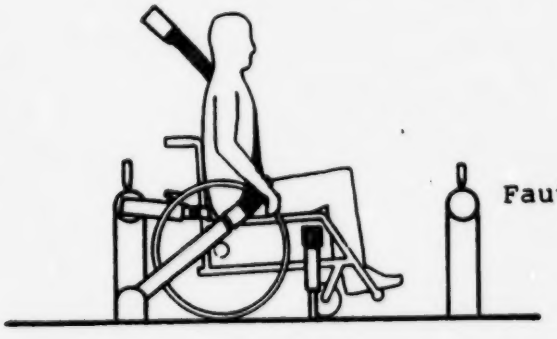


Fauteuil électrique standard



Fauteuil type "scooter"

Note: Le passager ne reste pas dans "scooter", mais fait le trajet dans un siège, à proximité.



Fauteuil type sport

FIGURE 2

Types de fauteuils acceptés - Concept 2

APPENDIX 5

QUESTIONNAIRE RAW AND PERCENTAGE SCORES

COMPARISON OF EXISTING SYSTEMS AND CONCEPTS

RAW SCORES

CRITERION	EXISTING			CONCEPT 1			CONCEPT 2		
	Excellent	Acceptable	Unacceptable	Excellent	Acceptable	Unacceptable	Excellent	Acceptable	Unacceptable
RAW SCORES									
Maintains settings	14	8	1						
Comfort / dignity	15	8		7	10	2	5	11	3
Ease of use	11	9	3	1	14	5		10	9
Ease of maintenance	13	9	1	3	13	2	4	10	2
Availability of spares	9	12	1						
Ease of installation	10	11	1	2	13	4		13	5
Wheelchair accommodation	11	9	3	5	12	2	3	10	5
Scooter accommodation	2	9	11	5	9	4	3	11	3
Emergency release	7	10	4	2	13	1	1	8	3
Durability	9	13							
PERCENTAGES									
Maintains settings	61%	35%	4%						
Comfort / dignity	65%	35%	0%	37%	53%	11%	26%	58%	16%
Ease of use	48%	39%	13%	5%	70%	25%	0%	53%	47%
Ease of maintenance	57%	39%	4%	17%	72%	11%	25%	63%	13%
Availability of spares	41%	55%	5%						
Ease of installation	45%	50%	5%	11%	68%	21%	0%	72%	28%
Wheelchair accommodation	48%	39%	13%	26%	63%	11%	17%	56%	28%
Scooter accommodation	9%	41%	50%	28%	50%	22%	18%	65%	18%
Emergency release	33%	48%	19%	13%	81%	6%	8%	67%	25%
Durability	41%	59%	0%						

APPENDIX 6

COMMENTS FROM RESPONDENTS

QUESTION 1: Is your existing system comprised of:

- A shoulder and lap belt?
- A lap belt only?

. Most passengers wear lap belts attached to their wheelchair.

QUESTION 3: Enclosed are specifications and descriptions for two proposed wheelchair securement/passenger restraint systems which meet applicable safety standards. Please indicate your reaction to these proposed systems by answering the following questions.

. I am unable to respond to your questions as I do not understand how it works either by explanation or by diagram. My reason for saying this, is that I do not understand how a driver could position a wheelchair into the tie down position, if it is as it appears, that the tie down position is stationary. Further to this, if the tie downs are stationary, I do not understand how you would get a wheelchair to the tie down location, if you had six tie downs in the vehicle, three on each side. If I have misunderstood, then I wonder, where you would store the systems when not in use.

QUESTION 4: Which securement/restraint system would you prefer to use, if purchase and installation costs were no obstacle:

- Your existing system
- Concept 1
- Concept 2
- Other (please specify)

. I would have to actually see all to make a good comparison.

QUESTION 9: How do you believe your use of the concept indicated in Question 5 will affect ridership:

- Increase
- No Change
- Decrease

. In present vehicle - concern re number of wheelchairs at one time.

QUESTION 15: Any comments or suggestions would be appreciated.

. Regular seats used by autonomous or semi-autonomous passengers, have been modified at our request, so that these people; particularly those having leg problems are seated at a 42 degree angle. Those seats are also retractable.

  This allows for more comfort for the passenger as well as more space in the vehicle.

  The power lifts used in our vehicles are "SAVARIN VII 200 - HYDROLIC".

. I can foresee problems in securing all types of chairs and especially in Concept #2 with securing the front down on fortress chairs. In Concept #1 I don't like the near harness set-up as it appears to be pulling inward on the chair and therefore would only assist the chairs to fold up on the passenger in some emergencies.

. From what I can determine from the drawings,both concepts would be unacceptable, since we operate our handicapped transit in a Ford Van which has accommodation for 2 wheelchairs, or 4 wheelchairs if one of the bench slats are removed. The room for wheelchairs is limited now and as well is restricted to how much the driver/operator can maneuver to fit 2 wheelchairs side by side. Using either of the proposed systems would restrict the space even more. As well, the cost seems very high and both seem awkward for the operator to secure wheelchairs and more time consuming than our present system.

. Your diagrams indicate that it would be very difficult to load a wheelchair in its position before securing same.

  Question! How do you load a wheelchair in its locking position if you are using converted vans?

. Concerns on Concept 1 and 2

  1. Mechanism for holding wheelchair could be difficult to avoid while loading or unloading other wheel chairs or walk ons.

  2. Tie down or cross shoulder straps could create a possible harrassment or assault charge from female passengers when straps are straightened when buckled up by operator.

- In Concept 1 the wheelchair is not being held down in the rear (nor is the scooter).

  Concept 2 may not serve a number of new "light alloy" wheelchairs we have seen.

- Figure 1, number 4 rear wheelchair restraint on Concept 1 unacceptable; would cause chair to collapse in accident:

  - systems could not be mounted side by side in our present vehicles and still allow access;

  - difficulty in maneuvering electronic chairs into position;

  - Concept 2 front restraint system may damage chairs.

- We have responded in the negative to securing scooters with both concepts. The basis for this is not the securement device but the integrity of the scooter itself once it is secured. If, through crash testing, it can be shown by using either concept that the integrity of the scooter can be maintained and withstand the forces identified in the Ontario Provincial Regulation, we would be most interested in the concept which meets that criteria.

- Both Concept 1 and Concept 2 appear to me to be hard for the driver or attendant to use. It would seem that one would have a tough time positioning the chair for tie down. Please keep me informed as to how your research progress.

- Pertaining to scooters=Transfer of customer is not done. Seating is limited and most customers prefer to stay on their machines. Is concept one faulty on this fact? Second: where the LAP and Shoulder harness pass under the arm rest; we are finding that new models of chair do not have this space. Will concept one work just as well if security seating device is placed under the lower arm rest panel? For maintenance on device: are they easy to repair or are special requirements needed?

- Concept 1 - It looks like the rear harness (item 1) might tend to collapse a folding style wheelchair in a sudden impact.

  Concept 2 - The pin/hole mechanism may be difficult to disengage after an impact.

  With both concepts the floor mounted structures look as if they may be difficult to maneover around.

- Time, space and maneuverability and random access a must for our operation. Concept appears to be for side walls of vehicle. We require circle positions as well for a total of 5-6 wheelchair positions on vehicle.

- Handi-buses use 5 different systems. Each bus is set-up for a certain run and wheelchair securement is set-up accordingly to accommodate certain types of wheelchairs on that particular run. With our systems, cost is kept to a minimum, and their needs and concerns are well attended to.

  Your concepts should be well rewarded, but to use it in our operation would greatly escalate our cost and minimize our space set out for wheelchair personnel.

- Our present vehicle is a modified van - concern re number of chairs to be accommodated.

- Though both of your new concepts seem very safe and well thought out. There are quite a few steps which would take much longer to secure and would inevitably cut down on the amount of trips we would be able to perform.

  The new systems would cut down on capacity given our type of vehicle.

- The preferred system would include the following:

  - The ability to store belts in the vehicles and to secure system without driver and passengers getting dirty.

  - Ease of cleaning system of dirt and ice (straps and pockets on floor).

  - Non rusting material.

QUESTION 15: Avez-vous des commentaires ou des suggestions? Veuillez les donner ci-dessous.

. Je trouve vos concepts tres securitaires, mais impossible a utiliser pour le genre de clientele que nous deservons et aussi pour l'espace que nous disposons dans nos vehicules.

. Apres avoir effectue une recherche, je constate que les deux (2) systemes que vous proposez ressemblent etrangement au systeme de fixation Q-STRAINT dont vous trouverez un exemplaire en annexe.

  La difference entre les deux (2) concepts que vous presentez et le Q-STRAINT, c'est qu'avec de dernier on ne retrouve rien au plancher qui puisse entraver de deplacement des personnes handicapee visuelles a bord de nos vehicules ou de la personne handicapee qui manipule elle-meme son fauteuil roulant ou meme le travail du chauffeur.

  Le systeme que nous utilisons presentement s'apparente au Q-STRAINT. Nous utilisons seulement les courroies d'ancrage au plancher. La personne handicapee en fauteuil roulant doit posseder une ceinture de securite a son fauteuil.

  En regardant le modele Q-STRAINT, vous pourrez remarquer les courroies que nous utilisons.

  Cependent, ces courroies s'adaptent mal aux fauteuils roulants electriques de marque FORTRESS ou DELTA. Nous avons demande aux fabriquants de ces fauteuils de modifier les points d'ancrage des fauteuils roulants afin qu'ils soient compatibles a nos fixations et ces derniers ont accepte notre proposition.

. Le systeme d'demcrage devait etre plus automatique et requirer moin de temps d'installation de l'usager.

APPENDIX 3

LIST OF OPERATORS RECEIVING QUESTIONNAIRE

Mr. Joe Buechles
Calgary Handi-Buses Association
220 - 36 Avenue N.E.
Calgary, Alberta
T2E 7E7

Ms. Jan Bell
Edmonton Handi-Buses Association
7630 Yellowhead Trail
Edmonton, Alberta
T5B 1G3

Ms. Joyce Anderson
P.S.S. "The Bus"
8530 Franklin Ave.
Fort McMurray, Alberta
P9H 2J3

Mr. Ken Blampied
Lethbridge Handi-Bus Association
Bell Kergan Centre
207 - 13th St. N.
Lethbridge, Alberta
T1H 2R6

Mr. Howard MacKey
Citizen's Action Bus
5210 - 61st Street
Red Deer, Alberta
T4N 6N8

Mr. Gary Campbell
Handi-Transit
873 Notre Dame Ave.
Winnipeg, Manitoba
R3E OM4

Mr. Kevin Sharpe
Phoenix Wheelchair Transportation
190 Drovencher Ave.
Winnipeg, Manitoba
R2H OG3

Mr. Jim Heron
Society for Crippled Children
and Adults
825 Sherbrooke Street
Winnipeg, Manitoba
R3A 1M5

Mr. Gary Paul
Vital Transit Services Ltd.
1850 Selkirk Ave.
Winnipeg, Manitoba
R2R ON6

Mr. Graham McQuat
Workman's Compensation Board
of New Brunswick
Box 160
Saint John, New Brunswick
H2L 3G9

Mr. David Scott
Handicab, The Hub Handivan
P.O. Box 13788
St. John's, Newfoundland
AlB 4G3

Mr. Donald Mielke
Access-A-Bus
Metro Transit Division
200 Ilsley Ave.
Dartmouth, Nova Scotia
B3B 1V1

Ajax Pickering Handi-Trans
1710 Kingston Road
Pickering Ontario
LlV 1C7

Mr. Doug Lamount
Barrie Accessible Community
Transportation Serivces
80 Bradford St., Unit 20
Barrie, Ontario
L4N 3A8

Ms. Linda Hill
Operation Life
P.O. Box 452
Brantford, Ontario
N3T 5N9

Mr. Mike Willis
Guelph Mobiliy Services Inc.
P.O. Box 1541
Guelph, Ontario
N1H 6N9

Mr. David Smith
Project Lift Inc.
280 Victor St. North
Unit 5
Kitchener, Ontario
N2H 5E2

Mr. Ian Carsley
London Paratransit "About Town"
24 Horton Street
P.O. Box 1889, Station A
London, Ontario
N6A 5J4

Mr. Douglas Manuel
Handi-Transit Incorporated
Box 1278, Station B
Oshawa, Ontario
L1J 5Z1

Ms. Sandy Southon
St. Catherine Transit
Handicapped Service
P.O. Box 2070, Station B
St. Catherine, Ontario
L2M 6P5

Sault Ste. Marie Transportation
Commission Para-Bus
111 Huron Street
Sault Ste. Marie, Ontario
P6A 5P9

Mr. Dave Koivisto
Handi-Transit
150 Castlegree Drive
Thunder Bay, Ontario
P7A 1T9

Ms. Sheila Palmer
Timmins Handi-Bus
506 Longregran Boul.
Timmins, Ontario
P4P 1C9

Ms. Joyce Pierce
Handi-Transit
3737 Walker Road
Windsor, Ontario
N8W 3S9

Ms. Debbie Walker
Wheel-Trans
1910 Young Street
Toronto, Ontario
M4S 1Z2

Mr. Jack Kane
Island Transit
308 Queen Street
Charlottetown, P.E.I.
C1A 7N8

Ms. Mariann Olchowy
Whitehorse Transit
102-3211 Third Avenue
Whitehorse, YT
Y1A 1G6

Mr. Robert Jans Cook
Du Page Transportation
1200 West Fulton Street
Chicago, Illinois
60607

Mr. Gordon Keats
Melville Handicar Van
P.O. Box 1240
Melville, Saskatchewan
S0A 2P0

Mr. Sherman Goodwin
Moose Jaw Transit System
228 Main Street N.
Moose Jaw, Saskatchewan
F6H 3J8

Mr. A.C. Morrison
Battleford's Handicapped Bus
System
P.O. Box 460
North Battleford, Saskatchewan
S9A 2Y6

Mr. Jim Feather
Saskatchewan Council For
Crippled Children
2310 Louise Ave.
Saskatoon, Regina
S7J 2C7

Mr. Alec Patterson
Swan Buses Ltd.
9607 112 Street
Grande Prairie, Alberta
T8V 3G3

Ms. Aileen Smalley
City of Brandon Transit System
P.O. Box 960
11th St. Queens Avenue
Brandon, Manitoba
R7A 6A2

Mr. David Seton
Corporation of the City of Chatham
315 King Street W.
P.O. Box 640
Chatham, Ontario
N7M 5K8

Mr. James Barber
Newmarket Transit
Box 328
171 Main Street S.
Newmarket, Ontario
L3Y 4X7

Mr. Peter Arnold
Ottawa-Carleton Regional
Transit Commission
1500 St. Laurent Blvd.
Ottawa, Ontario
K1G 0Z8

Mr. Doug McLean
Woodstock Transit
P.O. Box 40
500 Dundas Street
Woodstock, Ontario
I4S 7W5

M. Real Clement
Transpec Outaouais
127 Jean Proulx
Hull, P.Q.
J8Z 1T4

M. Bernard Decelles
Mouvement d'action d'handicapes de
Granby Inc.
33 Fairfield
Granby, PQ

M. Marcel Tremblay
Autobus Grise/Larose
1515 Marie Victorin
St. Bruno, PQ
J3V 4P6

M. Jacques Moquin
Corporation municipale de transport
de Sherbrooke
895 Cabano
Sherbrooke, Quebec
V1K 2H3

Ms. Louise Labrecque
Chef de service des Tranports
Centre François-Charon
525 Boul Hamel
Québec
G1M 2S8

M. Marc Dostie
6957 Wolse Street
Lac Megantic, PQ
J6B 2S3

M. Beniot Gendron
Commission de Transport de la
Communaute Urbaine de Montréal
8680 Esplanade
Montréal, Québec
H2P 3S2

APPENDIX 4

QUESTIONNAIRE RESPONSES

WHEELCHAIR SECUREMENT AND PASSENGER RESTRAINT QUESTIONNAIRE

1. Who is the manufacturer, and what is the model number/name of the wheelchair securement system you are using now? (If you are now using more than one type of system, please quote the one you consider, overall, the most satisfactory in Questions 1 and 2.)

Weco	4
Q-Straint	6
Aeroquip FF 865	3
Braun L1011	1
Ricon R30	1
No Response	7
Other	1
Total	23

Is your existing system comprised of:

A shoulder and lap belt?

Yes	9
No	5
No Response	9
Total	23

A lap belt only?

Yes	3
No	7
No Response	9
Total	23

2. Please rate your existing wheelchair securement and passenger restraint system by:

	Excellent	Acceptable	Unacceptable	No Resp
Maintains initial settings - no need to check, tighten, or re-adjust fittings during transportation.				
RESPONSES:	14.	8.	1.	0.
Comfort/personal dignity of passengers				
RESPONSES:	15.	8.	____.	0.

Ease of use for drivers and attendants eg. amount of time needed to secure wheelchairs and restrain passengers

	Excellent	Acceptable	Unacceptable	No Resp
RESPONSES:	11.	9.	3.	0.

Ease of maintenance.

RESPONSES:	13.	9.	1.	0.

Availability of spare parts.

RESPONSES:	9.	12.	1.	1.

Ease of installing system on vehicle

RESPONSES:	10.	11.	1.	1.

Ability to accommodate different makes and sizes of wheelchairs

RESPONSES:	11.	9.	3.	0.

Ability to accommodate scooters

RESPONSES:	2.	9.	11.	1.

Emergency release

RESPONSES:	7.	10.	4.	2.

Durability of system

RESPONSES:	9.	13.	.	1.

3. ENCLOSED ARE SPECIFICATIONS AND DESCRIPTIONS FOR TWO PROPOSED WHEELCHAIR SECUREMENT/PASSENGER RESTRAINT SYSTEMS WHICH MEET APPLICABLE SAFETY STANDARDS. PLEASE INDICATE YOUR REACTION TO THESE PROPOSED SYSTEMS BY ANSWERING THE FOLLOWING QUESTIONS:

CONCEPT 1	Excellent	Acceptable	Unacceptable	No Resp

Ease of Installing system on vehicles

RESPONSES: 2. 13. 4. 4.

	Excellent	Acceptable	Unacceptable	No Resp
Ease of use for drivers or attendants				
RESPONSES:	1.	14.	5.	3.
Comfort/personal dignity of passengers				
RESPONSES:	7.	10.	2.	4.
Ease of maintenance				
RESPONSES:	3.	13.	2.	5.
Emergency release				
RESPONSES:	2.	13.	1.	7.
Ability to accommodate different makes and sizes of wheelchairs				
RESPONSES:	5.	12.	2.	4.
Ability to accommodate scooters				
RESPONSES:	5.	9.	4.	5.

CONCEPT 2	Excellent	Acceptable	Unacceptable	No Resp
Ease of Installing system on vehicles				
RESPONSES:	____.	13.	5.	5.
Ease of use for drivers or attendants				
RESPONSES:	____.	10.	9.	4.
Comfort/personal dignity of passengers				
RESPONSES:	5.	11.	3.	4.

	Excellent	Acceptable	Unacceptable	No Resp

Ease of maintenance

RESPONSES: 4. 10. 2. 7.

Emergency release

RESPONSES: 1. 8. 3. 11.

Ability to accommodate different makes and sizes of wheelchairs

RESPONSES: 3. 10. 5. 5.

Ability to accommodate cooters

RESPONSES: 3. 11. 3. 6.

4. Which securement/restraint system would you prefer to use, if purchase and installation cost were no obstacle:

- o Your existing system 15
- o Concept 1 4
- o Concept 2 2
- o No response 2

5. Which system would you prefer to use, given estimated purchase and installation costs?

- o Your existing system 16
- o Concept 1 3
- o Concept 2 2
- o No response 2

IF YOU HAVE SELECTED CONCEPT 1 OR CONCEPT 2 IN QUESTION 5, PLEASE ANSWER THE FOLLOWING QUESTIONS. OTHERWISE, PLEASE SKIP DOWN TO QUESTION 12.

6. If the preferred concept you checked in Question 5 was not available, would you consider the other concept to be acceptable?

YES 4. NO 1.

7. How would the concept indicated in Question 5 affect the

efficiency of your operation considering vehicle boarding/deboarding times?

- o More effective 2
- o No change 3
- o No response 0

8. Your use of the concept indicated in Question 5 might permit several changes to your operation (eg. installation, maintenance, passenger boarding, passenger capacity). How do you believe the concept will affect your operating costs?

- o No change 4
- o Costs will increase 1
- o No response 0

9. How do you believe your use of the concept indicated in Question 5 will affect ridership:

- o No change 3
- o No response 2

10. If your preferred concept indicated in Question 5 was available would you replace existing securement/restraint systems immediately or gradually phase in the new equipment?

- o Gradual phase-in over several months
  Months required for phase-in: _____.

One firm stated that eight (8) months would be required for phase-in; a second required twelve (12) months. The two other respondents requiring the devices said that there would be a gradual phase-in but did not specify the transition time.

11. How many of the proposed systems would you require?

Four respondents would require a total of 61 systems; the fifth respondent did not provide a specific number.

12. How many vehicles which can accommodate wheelchairs do you presently operate?

The twenty-three operators collectively operate 387 vehicles. The smallest company operates one vehicle; the largest operates over one hundred. The average fleet size is 17 vehicles.

13. Approximately how many disabled persons do you

transport in an average week? (One person on a return trip counts as two).

The twenty-three operators collectively carry 38,202 persons per week. The smallest carries 30 persons; the largest 11,000. The average is 1660 persons/week.

14. What percentage of your passengers are wheelchair users?

Maximum	90%
Minimum	8%
Weighted average	41%

APPENDIX "E"

Operation and Installation Instructions

WHEELCHAIR SECUREMENT SYSTEM FOR VANS AND SMALL BUSES

OPERATIONAL PROCEDURES, STORAGE DETAILS AND INSTALLATION INSTRUCTIONS

October 1988

Prepared For

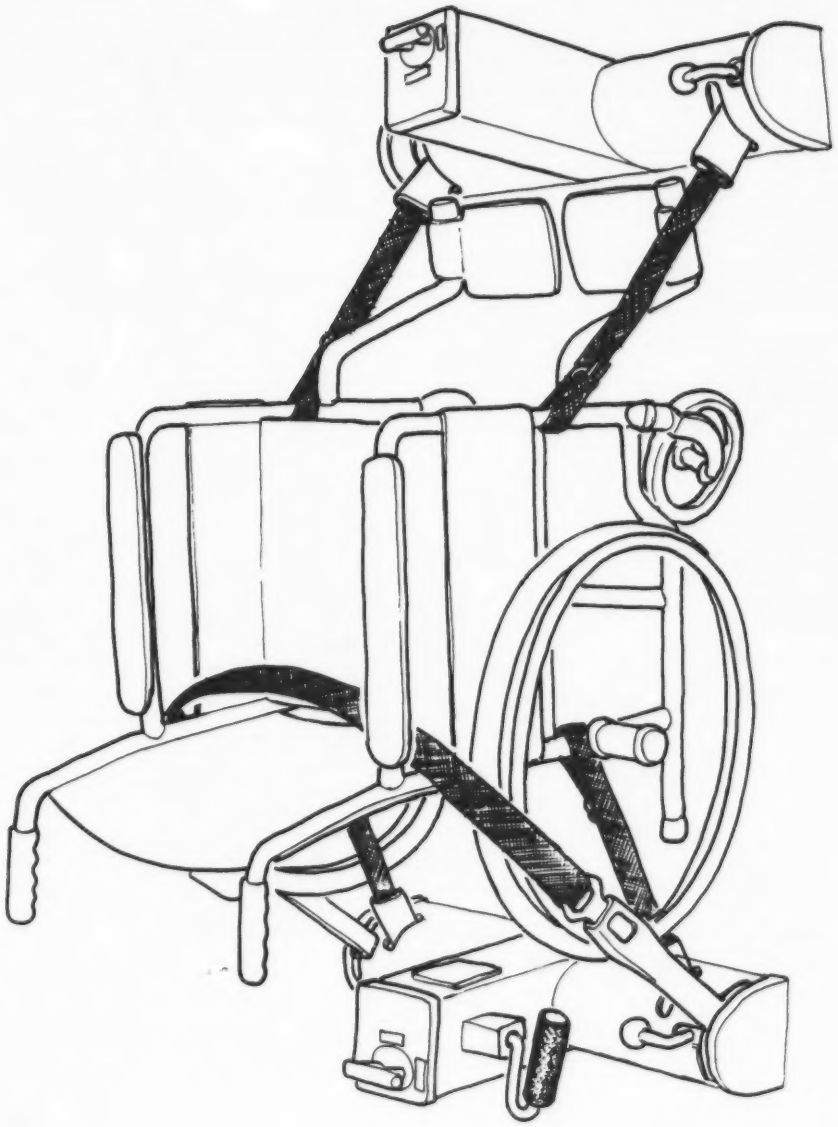
TRANSPORTATION DEVELOPMENT CENTRE

By

T E S Limited

T E S Report Number: C839-4

E1



WHEELCHAIR SECUREMENT SYSTEM FOR VANS AND SMALL BUSES

OPERATIONAL PROCEDURES

1. Position the wheelchair facing forwards between the front and rear securement units. Engage the handbrakes on the wheelchair.

2. Turn the handle on the front securement unit post to the "unlock" position.

3. Unhook the left and right webbing from the storage hooks. Wrap the webbing around the wheelchair frame at the highest convenient location. (The webbing wraps around the frame member and hooks back on itself through the D-ring).

   NOTE: Never attach the hook to the wheel or axle of the wheelchair.

4. Turn the handle on the front securement unit post to the "lock" position.

5. Turn the handle on the rear securement unit post to the "unlock" position.

6. Pull out the webbing from the rear securement unit and secure the left and right wheelchair frame members as in step 3. (Attachment of the webbing to the frame members must be made at the highest convenient location.)

7. Turn the handle on the rear securement unit post to the "lock" position.

8. Turn the curved handle on the side of the post clockwise to tighten the webbing, being careful not to damage the wheelchair frame by overitghtening.

To release the restraint system, the above operations (Steps 1 through 8) are performed in the reverse sequence. (NOTE: To release the rear restraint webbing, the tension must be slackened by turning the curved

handle clockwise an eighth of a turn while unlocking.)

9. Secure the occupant with the passenger restraint belt on the rear unit.

NOTE: The lap belt should be passed around the occupant and down either between the side panel and the seat of the chair or through the gap between the chair back and the seat behind the occupant. Never put the belt over the arm rests or the side panels. When snug, the belt should cross the pelvic zone of the occupant.

STORAGE DETAILS

The front and rear securement units can be pivotted inward for storage when not in use. THis is accomplished by turning and lifting up the floor latch lever, located on the aisle side of each unit, and rotating the units inward towards the wall. This feature doubles as an emergency release system by slackening the webbing sufficiently for release, should a retractor malfunction.

NOTE: This restraint system easily adapts to almost any size or design of wheelchair and provides positive securement in all directions. However, passengers using scooters must transfer to another seat. The unit can then be used to secure the scooter alone.

INSTALLATION INSTRUCTIONS

a. Refer to Figure 1 and the following instructions to prepare the bus floor for the installation of the wheelchair securement system.

1. Position a pivot floor plate (ITEM No. 1) at the location shown in Figure 1. Orient the plate with the threaded stud nearest the wall.

2. Using the plate as a template, mark and drill four 0.563 in. (14 mm) diameter holes vertically through the bus floor. A magnetic base drill is recommended for this procedure.

3. Reposition the pivot floor plate over the holes. Install a flat head screw (ITEM NO. 5) in each of the holes.

4. Position a pivot sub floor plate (ITEM NO. 2) on the underside of the floor, with the mounting holes engaged with the screws installed in step 3. Secure together using a fender washer (ITEM 6) and locknut (ITEM 7) at each screw location.

5. Position a floor plate (ITEM 3) at the location shown in Figure 1. Orient the plate with the central hole nearest the wall.

6. Using the plate as a template mark and drill two 0.438 in. (11 mm) diameter holes vertically through the bus floor. A magnetic base drill is recommended for this procedure.

7. Reposition the floor plate over the holes. Install a flat head screw (ITEM 8) in each hole.

8. Position a sub floor plate (ITEM 4) on the underside of the floor, with the mounting holes engaged with the screws installed in step 7. Secure together using a fender washer (ITEM 9) and locknut (ITEM 10) at each screw location.

9. Repeat steps 1 through 4 to install the second pivot floor plate and sub floor plate at the location shown.

10. Repeat steps 5 through 8 to install the second floor plate and sub floor plate at the location shown.

B. Refer to the following instructions to install the wheelchair

securement system.

1. The securement system is composed of front and rear securement units. The front unit (ITEM 11) is identified by two pivoting retractors in the curved base. The rear unit (ITEM 12) is identified by a curved handle on the side of the center post. The units must be positioned with the webbing facing inward towards the designated securement location.

2. Remove the curved black cover from the wall side of the front unit. Position the unit over the 3/4-16 UNC threaded pivot of the plate previously installed. Secure using 2 belleville washers (ITEM 13) and a 3/4-16 UNC nut (ITEM 14). Reinstall the cover.

3. Repeat step 2 for the rear unit.

4. Lift the floor latch lever on the aisle side of both units and rotate the units to engage with the holes in the floor plates installed previously.

PARTS LIST

ITEM NO.	ITEM	QUANTITY
1	Pivot Floor Plate	2
2	Pivot Sub Floor Plate	2
3	Floor Plate	2
4	Sub Floor Plate	2
5	1/2-13 x 4 Flat Hd Screw	8
6	1/2 Fender Washer	8
7	1/2-13 Nylon Locking Nut	8
8	3/8-16 x 4 Flat Hd Screw	4
9	3/8 Fender Washer	4
10	3/8-16 Nylon Locking Nut	4
11	Front Restraint Unit	1
12	Rear Restraint Unit	1
13	3/8 Belleville Washers	4
14	3/4-16 Nut	2

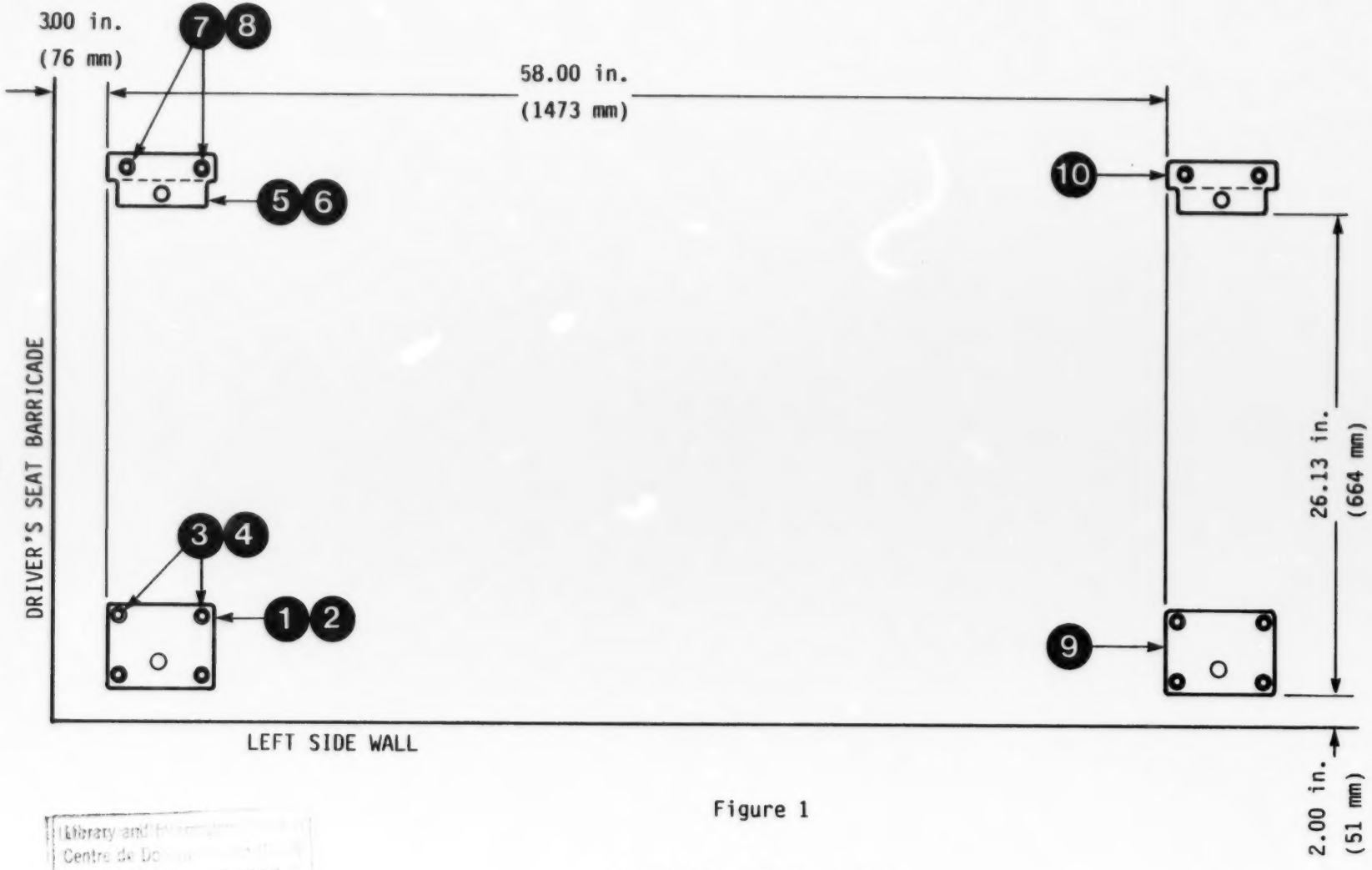


Figure 1

Location of Floor Plates

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